2.5 Effects of the Action

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

2.5.1 Effects of the Action on the Species

Impacts to Central Valley fall/late-fall run Chinook salmon from the PA are analyzed in this Opinion even though the Central Valley fall/late-fall run Chinook salmon ESU is not listed under the ESA. There are three primary reasons that we included the analysis of project effects to fall/late-fall run Chinook salmon: 1) to inform the prey base effects analysis for Southern resident killer whale; 2) relationship between fall/late-fall and listed Chinook salmon covered in this Opinion (spring-run and winter-run) relative to quantity and quality of effects to these species, which makes fall/late-fall an appropriate surrogate in some cases for the listed Chinook salmon; and 3) utility of the Opinion effects analysis for Pacific Salmon (fall/late-fall, spring-run and winter-run Chinook salmon) as a consistent foundation for the EFH analysis.

Because fall/late-fall Chinook salmon are not an ESA-listed species and do not have designated critical habitat, this species will not be evaluated based on a jeopardy or adverse modification standard. Therefore, fall/late-fall Chinook salmon are only addressed in the Effects of the Action section of this Opinion because their relative species status both rangewide and within the action area (i.e., environmental baseline) are irrelevant to the Opinion's conclusion. Life-history information for fall/late-fall Chinook salmon is presented in the EFH Assessment as the foundation for evaluating impacts to essential fish habitat for this ESU.

Due to the variability and uncertainty associated with the response of anadromous fish species to the effects of the PA, the varying population size of each species, annual variations in the timing of spawning and migration, and individual habitat use within the action area, it will be difficult to quantify and track the amount or number of individuals at each life stage of each species that will be adversely affected. Because of this, we have used the following terms to provide some information on expected amount: small proportion, medium proportion, or large proportion.

2.5.1.1 Construction Effects

The PA includes both aquatic and terrestrial construction-related activities that are expected to create acoustic impacts to aquatic species in specific locations or "activity areas" within the action area. As described in the BA, each activity has a proposed in-water work window, described in Table 2-1.

Table 3-1. Proposed In-Water Construction Work Windows

Construction Locations/Activities	Timeframe (Months)
North Delta Intakes	June 1 to October 31
Head of Old River Gate	August 1 to October 31
Clifton Court Forebay	July 1 to November 30
Geotechnical Investigations	August 1 to October 31
Barge Landings	August 1 to October 31

2.5.1.1.1 Acoustic Stress

Major activities included in the PA that have potential to cause acoustic impacts include using heavy construction equipment, excavators or drilling equipment, and pile drivers. Stress from noise can also be expected due to increased vessel traffic for delivery of construction equipment and materials and operation of tunnel boring machines (TBMs) under Delta waterways. Acoustics-related stress is considered a direct effect of the construction activities included in the PA.

Construction activities within the aquatic environment are described in the BA for multiple locations throughout the Delta. These activities include driving steel sheet pile sections for cofferdam construction and steel or concrete support pilings for infrastructure. The BA proposes using vibratory hammers to initially drive the sheet piles to the approximate final depth required and impact hammers to achieve the final required tip depth and load-bearing strength. Installing the sheet pile cofferdams will take several construction weeks, as described in BA Chapter 3 and Appendix 3D, after which the isolated construction area will be dewatered for continued construction activities. Installation of steel support piles assumes exclusive use of an impact hammer to drive piles to the required depth and the load-bearing resistance necessary to support concrete floor foundations.

Installing piles with either a vibratory or impact hammer is expected to result in adverse effects to salmonids and sturgeon due to high levels of underwater sound, but to differing degrees. NMFS considers using a vibratory hammer to be less harmful to fish than that of an impact hammer because of the continuous characteristics of the sound wave produced by a vibratory hammer. While exposure to continuous sound for a long duration could harm fish, noise from an impact hammer is an impulsive sound source with a high intensity and rapid rise time and is known to injure or kill fish.

Driving sheet and pipe piles creates a wave of energy that propagates from the pile location. Sheet and steel pipe piles are driven into the substrate until the hammer encounters a predetermined level of resistance. As the pile is driven into the substrate and meets resistance, a wave of energy travels down the pile, causing it to resonate radially and longitudinally, much like a large bell. Most of the acoustic energy results from the outward expansion and inward contraction of the walls of the steel pile as the compression wave moves down the pile from the hammer to the end of the pile buried in the substrate. Because water is virtually incompressible, the outward movement of the pile followed by the pile walls pulling back inward to their original shape sends an underwater pressure wave that propagates outward from the pile in all directions.

The pile resonates, sending a succession of pressure waves as it is pushed several inches deeper into the substrate.

The physical injury or damage to body tissues associated with very high sound level exposure and drastic changes in pressure are collectively known as barotraumas. Fish can survive and recover from some barotrauma, but in other cases, death can be instantaneous, occur within minutes after exposure, or occur several days later. The degree to which an individual fish is affected by underwater sound exposure depends on a number of variables including differences in sensitivity to acoustic pressure, fish species, presence of a swim bladder, hearing sensitivity, the proximity and linkage of the swim bladder to the inner ear, and fish size (Popper et al., 2003; Ramcharitar et al., 2006; Braun & Grande 2008; Deng et al., 2011). Because the air within a fish's swim bladder is less dense than water or the fish body, the air and swim bladder can be easily compressed by sound pressure waves traveling through the fish's body. As sound pressure waves pass through the fish's body, the swim bladder routinely expands and contracts with the fluctuating sound pressures, resulting in injury through the routine expansion and contraction of the bladder. The characteristics of the sound source also play an important role in effect to fish. For high sound pressure level exposure, such as impact hammer pile driving, the swim bladder may rapidly and repeatedly expand and contract and pound against the internal organs. This pneumatic pounding may result in hemorrhage and rupture of blood vessels and internal organs, including the swim bladder, liver, and kidneys. External damage such as loss of scales or hematoma in the eyes or at the base of fins has also been documented (Yelverton et al., 1975; Wiley et al., 1981; Linton et al., 1985; Gisiner 1998; Godard et al., 2008; Carlson et al., 2011; Halvorsen et al., 2012a; Halvorsen et al., 2012b; Casper et al., 2012).

The severity of injury sustained by a fish may also be dependent upon the amount of air in the swim bladder during sound exposure, which characterizes the state of buoyancy (Govoni et al., 2003; Halvorsen 2012a; Stephenson et al., 2010; Carlson 2012), and the physiological state of fish at the time of exposure. For example, a deflated swim bladder (i.e., negatively buoyant) could put the fish at a lower risk of injury from the sound pressure exposure compared to a fish with an inflated swim bladder (i.e., positively buoyant). Given the rapid rise time of impact hammer pile driving, however, the inability of fish to quickly regulate buoyancy and the inability to know the buoyancy state of the fish during exposure to these sound sources, NMFS assumes the worst case scenario: that swim bladders are positively buoyant, and, therefore, exposed fishes could be subjected to the highest degree of trauma.

Besides injuries to the soft tissues surrounding the swim bladder, additional acoustic-related injuries can occur within the auditory structures of fish exposed to high intensity sounds. Injury from exposure to high levels of continuous sound manifests as a loss of hair cells of the inner ear (Popper and Hastings 2009), which may result in a temporary decrease in hearing sensitivity or temporary threshold shift (TTS).

TTS is considered a temporary reduction in hearing sensitivity due to exposure durations lasting a few minutes to hours. This type of noise-induced hearing loss in fishes is generally considered recoverable because fish, unlike mammals, are able to regenerate damaged hair cells (Smith et al., 2006). An important consideration when evaluating auditory structure damage due to noise is determining the sound level at which hearing loss has significant implications for behavior and associated fitness consequences, such as preventing individuals from detecting biologically relevant signals. Hastings (2002) expected damage of auditory hair cells in salmon to occur with exposure to continuous sound at about 200 dBrms, which equates to a peak sound level of 203-dB peak as the onset of damage to the sensory hearing cells of salmon.

Beyond barotrauma-related tissue damage, additional direct physiological effects to fishes from exposure to sound include increases in stress hormones or changes to other biochemical stress indicators (Sverdrup et al. 1994; Santulli et al. 1999; Wysocki et al. 2006; Nichols et al. 2015). These effects can affect both predation risk by compromising predator evasion and feeding success by affecting prey detection, leading to reduced fitness or survival success.

Besides direct physical injury because of the sound pressure wave, underwater sounds have also been shown to alter the behavior of fishes (see review by Hastings and Popper 2005; Hawkins et al. 2012; Popper et al. 2014). There is significant variation among species. The potential for adverse behavioral effects will depend on a number of factors, including the sensitivity to sound, the type and duration of the sound, and the life stages of fish present. Observed behavioral responses to anthropogenic sounds may include startle responses, changes in swimming directions and speeds, increased group cohesion and bottom diving (Engas et al., 1995; Wardle et al., 2001; Mitson & Knudsen 2003; Boeger et al., 2006; Sand et al., 2008; Neo et al., 2014), and “alarm” as detected by Fewtrell et al. (2003) and Fewtrell and MacCauley (2012).

The startle response in fishes is a quick burst of swimming that may be involved in avoidance of predators (Popper 1997). Other potential changes in behavior in response to underwater sounds include reduced predator awareness and reduced feeding (Voellmy et al., 2014;, Simpson et al., 2015) and changes in distribution in the water column or schooling behavior (e.g., Skalski et al., 1992; Feist et al., 1992; Engås et al., 1996; Engås & Løkkeborg 2002; Slotte et al., 2004). A fish that exhibits a startle or other behavioral response may not necessarily be injured, but is exhibiting behavior that suggests it perceives a stimulus that indicates potential danger in the immediate environment. Therefore, these types of responses likely do not have a fitness consequence for the individual unless the reaction increases susceptibility to predation or some other negative effect.

The tolerance of sound pressure levels causing either direct injury or behavioral responses varies among species and life stage. Adult salmonids, because of their large size, can usually tolerate higher pressure levels (40-50 psi) (Hubbs and Rechnitzer 1952), so immediate mortality rates for adults are expected to be less than those for juvenile salmonids. However, some uncertainty regarding the relative sensitivity of larger fishes remains (Halvorsen et al. 2012). Given that adult green sturgeon are on average significantly larger than salmon, they could, presumably, tolerate higher levels of sound pressure and be less affected by pile-driving activities. Similarly, juvenile green sturgeon are typically around 600 millimeters long by the time they inhabit the Delta. Because of the similarity in size to adult salmonids, juvenile green sturgeon are expected to be more tolerant than juvenile salmonids of temporary sound disturbances associated with pile driving. Green sturgeon are vulnerable to injury or death from pile driving, however, especially if within close proximity, as demonstrated by the lethal sound pressure levels (SPLs) resulting in the death of a white sturgeon (likely a juvenile) documented during the construction of the Benicia-Martinez Bridge.

Criteria have been established to support assessing acoustics effects to west coast fish species. The Fisheries Hydroacoustic Working Group (FHWG), which consists of representatives from NMFS, USFWS, the Federal Highway Administration, and the West Coast Departments of Transportation, established interim thresholds to assess physical injury to fish exposed to underwater sound produced during pile driving. Thresholds include a single strike peak sound pressure level of 206-dB (re: 1 μPa) and an accumulated sound exposure level (cSEL) of 187-dB (re: 1 μPa^2-sec) for fish greater than two grams and 183-dB (re: 1 μPa^2-sec) for fish less than two grams. Physical injury is assumed to occur if either the peak or cSEL threshold is exceeded. The SEL limit referred to as "effective quiet," however, can be used to identify the distance beyond which no physical injury is expected from a single strike, regardless of the number of strikes. The effective quiet currently assumed for fish is 150-dB (re: 1 μPa^2*sec). When the received SEL from an individual pile strike is below this level, the accumulated energy from multiple strikes is not expected to contribute to injury, regardless of how many pile strikes occur. The effective quiet level is used to identify the maximum distance from the pile where injury to fishes is expected. It is the distance at which the single-strike SEL attenuates to 150dB.

In areas where we have limited information, we have developed assumptions about fish behavior and the recovery time of affected tissue to determine fish response (i.e., avoidance, injury, and death) based on the limited available information. Sonalysts (1997) suggested that although fish (including Atlantic salmon) exhibit a startle response during the first few acoustic exposures, they do not move away from areas of very loud underwater sounds and can be expected to remain in the area unless they are carried away by currents or normal movement patterns. Therefore, NMFS assumes that fish will remain in the vicinity of a construction site unless currents or behavior patterns unrelated to loud underwater sound avoidance would indicate that movement is likely to occur.

Although there may be some tissue recovery between the completion of one pile and the beginning of driving at the next, given the level of uncertainty that exists, NMFS will sum the underwater sound energy produced during the installation of all piles on any given day until a break of 12 hours or longer occurs to determine potential physical effects to listed salmonids and sturgeon each day pile driving occurs. NMFS assumes that normal behavior patterns will move any migrating salmonids and green sturgeon out of the affected area within one day, and therefore, underwater sound energy will not be summed over consecutive days. This would not be the case if the construction site were located in an area where either adult salmonids or sturgeon were spawning or juveniles were rearing for extended periods of time in the action area, in which case they could experience repeated exposures.

While aquatic ecosystems can logically be expected to experience some degree of effect from construction activities within the aquatic environment, construction activities in non-aquatic (i.e., terrestrial) areas have potential to cause acoustic stress to aquatic species as well because noise generated by sheet pile wall installation in upland areas can transmit sound into adjacent waterways (Burgess and Blackwell 2003). Because the noise generated by terrestrial activities is expected to attenuate relatively quickly, however, it is unlikely that the resulting noise level in the waterway will cause mortality or injury. Instead, it will more likely cause behavioral responses that may result in harassment or other effects such as increased predation risk or a decreased ability to detect biologically-relevant sounds in the surrounding environment. It is anticipated that aquatic noise levels resulting from terrestrial activities may initially deter fish from the affected area, although they may return or stay in the area as they habituate to the new acoustic environment. Because noise coupled with increased human activity (i.e., motion, shadows, etc.) may be sufficient to deter fish from the work area for long periods of time, NMFS expects that any fish within the areas adjacent to land-based construction activities will avoid the shoreline and move into deeper, open water, where predation stress is greater. The additional noise caused by land-based activities may also mask important ecological reception of sounds necessary for the detection of nearby predators or increase stress hormones that may affect predator avoidance and prey detection. Therefore, elevated noise within the aquatic environment may potentially expose fish to increased predation risk due to reduced use of shallow shoreline refuge areas, increased masking of predators within the immediate areas, and reduced response to avoidance cues.

The use of several TBMs to cut underground tunnels through the Delta sediment horizons will create both vibrations and low frequency noise due to the operational sounds of the machines and the action of the rotating cutterheads grinding through the native soils. Tunneling projects in several different countries have experienced situations in which TBMs tunneling beneath occupied areas have produced vibrations and low frequency noise that could be perceived at the surface.

Fish are particularly sensitive to low frequency linear accelerations (i.e., infrasound). The otolith organs responsible for the detection of infrasound are sensitive enough to detect noise generated by a swimming fish. This ability is thought to be important in courtship behavior and predator-prey interactions. Knudsen et al. (1997) and Sand et al. (2001) reported that Chinook salmon, rainbow trout (*O.mykiss*) and European silver eels (*Anguilla anguilla*) were sensitive to infrasound at the 10-Hz level and were actively deterred. Fish exposed to the noise source avoided or fled the area. Habituation to the noise did not occur even after repeated exposures. Thus, the infrasound created by the TBMs along the tunneling alignment at the cross waterways may cause behavioral responses that result in fish altering their use of waterways, which affects migratory routing and potential habitat accessibility.

2.5.1.1.1.1 Pile Driving

The proposed action includes extensive pile-driving activities throughout the construction period at the north Delta diversion intake locations, Clifton Court Forebay, the Head of Old River, and barge landing locations. Activities at each location are described below. The proposed action also includes protocols designed to minimize the potential exposure of listed fish species to pile-driving noise by conducting all pile driving within work windows when most species are least likely to occur in the action area. DWR will follow standard and provided AMMs, including development and implementation of an underwater sound control and abatement plan outlining specific measures that will be implemented to avoid and minimize the effects of underwater construction noise on listed fish species (Appendix 3.F *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). These measures may include various methods of sound energy attenuation that will act to change and dissipate the energy (Christopherson et al 2002).

Proposed methods include using vibratory and other non-impact driving methods as well as other physical and operational measures to limit the intensity and duration of underwater noise levels when listed fish species may be present. Where impact pile driving is required, hydroacoustic monitoring will be performed to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded. To minimize pile-driving noise for sheet pile installation, sheet piles will first be driven into the channel bottom using a vibratory hammer to the greatest extent practicable, then an impact hammer will be used to drive the piles to their final tip elevation.

2.5.1.1.1.1.1 North Delta Intake Locations

The construction of the NDD requires extensive pile driving. According to the PA, pile-driving activities at the NDD intake locations is expected to last from 2022 through 2026, with sheet or foundation piles being driven throughout this period. The project description includes a proposed in-water work window of June 1 to October 31 for the NDD intake locations for each construction year. The risk of injury to fish is highest in the early part (June) of the first work season for each intake because sheet piles for cofferdam installation will occur in the wetted channel during this early phase of each intake's construction. Pile-driving activities will be staggered to occur at each of the three intakes of the NDD (Intakes 2, 3, and 5) in different years. In most years, there will only be active in-water work occurring at one diversion intake at a time. In 2025, sheet pile driving at Intake 2 is proposed to occur simultaneously with foundation pile driving at Intake 3, which is two river miles downstream. As noted in section *2.5.1.1.1.1 Pile Driving*, the action agency has included AMMs to minimize impacts of the activity. These include using a vibratory hammer for approximately 70 percent of the driving and including BMPs for sound attenuation.

Details of the proposed pile installation activities at the three intakes of the NDD (Intakes 2, 3, and 5) are shown in

Table 3-2. At each location, all sheet pile driving required for cofferdam installation is expected to be completed within a single year's work window by using multiple pile drivers at each intake location. Similarly, using multiple drivers at a location is expected to result in all foundation piles at a single location being installed within a single work window, though in a year subsequent to cofferdam construction.

Table 3-2. Intake Sheet Pile Installation Details

Task Name	River Mile	Duration (days)	Start Date	End Date	Number of Piles	Extension into River (ft)	Length (ft)	Number of Concurrent Drivers	Number of Piles Driven Per Day Per Driver
Intake 2 Sheet piles	41.1	110	6/2/2025	10/31/2025	2500	60	2000	4	15
Intake 2 Foundation piles	41.1	19	6/1/2026	10/31/2026	1120 (42 in)			4	
Intake 3 Sheet piles	39.4	109	6/3/2024	10/31/2024	2500	60	1600	4	15
Intake 3 Foundation piles	39.4	42	6/2/2025	10/31/2025	850 (42 in)			4	

Intake 5 Sheet piles	36.8	42	6/2/2022	10/31/2022	2500	60	2000	4	15
Intake 5 Foundation piles	36.8	19	6/1/2023	10/31/2023	1120 (42 in)			4	

While the PA provides the information in

Table 3-2, complete acoustics analysis still requires several assumptions for information that cannot be completely determined at this early stage of project design. NMFS assumes no sound attenuation methods (other than vibratory hammer use) will be used during installation of the sheet piles because the location and configuration of the cofferdam may prevent implementing additional sound attenuation methods. As clarified by DWR during consultation discussions, NMFS assumes that the 42-inch steel piles of the intake foundations will first be driven with a vibratory hammer. An impact hammer is expected to be used for final driving, which is expected to produce very high levels of sound pressure. The foundation piles are expected to be driven within a dewatered cofferdam or behind a bubble curtain, however, which will reduce the extent of the water column that is affected by deleterious underwater noise levels. Multiple pile drivers are expected to be used at each intake location. According to the PA and information provided by DWR, a maximum of four pile drivers may be required to meet the proposed work schedule. NMFS has used this as an assumption for analysis of effects of pile-driving activities on salmonids and sturgeon. Specifically, these assumptions were used to identify the area of potential injury and mortality associated with the sound pressure levels as quantified by the distance to reach "effective quiet," the distance beyond which no physical injury is expected from a single strike, regardless of the number of strikes.

Based on this information, NMFS has identified the distances at which sound pressure thresholds for fish are anticipated to be met for each pile driving scenario and intake location. For the construction of Intakes 2, 3, and 5 using four pile drivers, NMFS does not anticipate sound pressure thresholds for fish to be exceeded beyond the following distances shown in Table 3-3:

Table 3-3. Distances at Which Sound Pressure Thresholds are Met

	Effective Quiet (187-dB SEL threshold)					Subinjurious Sound Levels (150-dB RMS)		Single Strike Peak Pressure 206-dB SPL
Task Name	**Distance to Effective Quiet (ft)**	**Lateral Distance of Impact Across River (ft)**	**Upriver Distance (ft)**	**Downriver Distance (ft)**	**Total River Distance (ft)**	**Distance of Impact Across River (ft)**	**Total River Distance (ft)**	**Distance (ft)**
Unattenuated Intake 2	2814	700	3228	3228	6463	13061	8214	29.5
Unattenuated Intake 3	2814	500	3228	3228	6463	13061	8214	29.5

	Effective Quiet (187-dB SEL threshold)					Subinjurious Sound Levels (150-dB RMS)		Single Strike Peak Pressure 206-dB SPL
Task Name	Distance to Effective Quiet (ft)	Lateral Distance of Impact Across River (ft)	Upriver Distance (ft)	Downriver Distance (ft)	Total River Distance (ft)	Distance of Impact Across River (ft)	Total River Distance (ft)	Distance (ft)
Unattenuated Intake 5	2814	600	3228	3228	6463	13061	8214	29.5
Attenuated Intake 2	1522	-	-	-	3871	15230	31286	20.0
Attenuated Intake 3	1522	-	-	-	3871	15230	31286	20.0
Attenuated Intake 5	1522	-	-	-	3871	15230	31286	20.0

Pile driving at intake locations is expected to create adverse acoustic conditions for any fish present during these actions.

Intake 2 is the most upstream intake location, but will be the last constructed (in 2025–2026). This location is on an outside bend of the eastern bank of the Sacramento River downstream of an 11,000-foot-long straight reach. From the Intake 2 site, the river gradually bends to the west to the site of Intake 3, 0.7 miles downstream. As shown in Table 3-3, the calculated distance to the 206-dB SPL single-strike threshold sheet pile installation is 30 feet, or approximately 4.3 percent of the channel width at that location (700 feet). Because the distance to the 187-dB SEL "effective quiet" threshold extends the zone of injury a total river length of 6,463 feet (1,970 meters) and the calculated distance to the 150-dB RMS threshold is nearly 13,000 feet, discernable impacts such as behavioral modification from the sheet pile driving at Intake 2 will extend upstream approximately 11,000 feet to the nearest channel bend and downstream approximately 7,000 feet until the 187-dB RMS threshold is reached.

For foundation pile installation, the distance to the 206-dB SPL threshold with attenuation created by the dewatered cofferdam is approximately 20 feet (6 meters) or approximately 2.9 percent of the channel width at that location (700 feet). The 187-dB SEL "effective quiet" threshold distance extends for a total distance of 3,871 feet from the Intake 2 site. Because the distance for the 150-dB RMS threshold is estimated at 31,286 feet (9,536 meters), the entire river length between the bends is expected to be affected.

Intake 3 is on a transitional point on the Sacramento River between two curves located approximately 2800 feet upstream and 2000 feet (600 meters) downstream of the intake site. Therefore approximately 7700 feet of river channel between the two bends may be impacted by the acoustics effects of pile driving. During the 2024–2025 construction period at this intake, the calculated distance to the 206-dB SPL single strike threshold for sheet pile installation is 30 feet, or approximately six percent of the channel width at that location (500 feet). Because the distance to the 187-dB SEL "effective quiet" threshold extends the zone of injury for a total river length of 6,463 feet (1,970 meters) and the calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet, discernable impacts such as behavioral modification from the sheet pile driving at Intake 3 will extend the full length of the 4800-foot-long straight reach between the nearest upstream and downstream bends.

For foundation pile installation, the distance to the peak 206-dB SPL threshold with attenuation created by the dewatered cofferdam is approximately 20 feet (6 meters) or approximately 4 percent of the 500-foot-wide river channel. The 187-dB SEL "effective quiet" threshold distance extends for a total distance of 3,871 feet from the Intake 3 site and will cover the width of the river. Because the distance for the 150-dB RMS threshold is estimated at 31,286 feet (9,536 meters), the entire river length between the bends is expected to be affected. Additionally, the sheet pile driving for Intake 2 during 2025 will potentially overlap with the foundation pile driving for Intake 3, creating a potential for approximately 2,400 feet of overlap for the 150-dB RMS threshold for behavioral effects if both sites have concurrent pile driving.

Intake 5, the first of the three intakes to be constructed, is on a relatively straight reach of the Sacramento River between two curves located approximately 6500 feet upstream and 6500 feet downstream of the intake site. Therefore, approximately 14,000 feet of river channel between the two bends may be impacted by the acoustics effects of pile driving at Intake 5. During the 2022-2023 construction period at this intake, the calculated distance to the 206-dB SPL single strike threshold for sheet pile installation is 30 feet, or approximately five percent of the channel width at that location (600 feet). Because the distance to the 187-dB SEL "effective quiet" threshold extends the zone of injury for a total river length of 6,463 feet (1,970 meters) and the calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet, discernable impacts such as behavioral modification from the sheet pile driving at Intake 3 will extend the full length of the 14,000-foot-long straight reach between the nearest upstream and downstream bends.

For foundation pile installation, the distance to the peak 206-dB SPL threshold with attenuation created by the dewatered cofferdam is approximately 20 feet (6 meters) or approximately 3.3 percent of the 600-foot-wide river channel. The 187-dB SEL "effective quiet" threshold distance extends for a total distance of 3,871 feet from the Intake 5 site and will cover the width of the river. Because the distance for the 150-dB RMS threshold is estimated at 31,286 feet (9,536 meters), the entire river length between the bends is expected to be affected.

2.5.1.1.1.1.1.1 Winter-run Exposure and Risk

The life history and spatial and temporal presence of winter-run Chinook salmon is described in *Section 2.4.1 Environmental Baseline*. General presence in the Sacramento River and Delta is shown in Table 2-4 which includes adult (a) and juvenile (b) winter-run in the Sacramento River. Darker shades indicate months of greatest relative abundance.

Table 3-4. The Temporal Occurrence of Adult (a) and Juvenile (b) Winter-run in the Sacramento River.

Winter run relative abundance	High				Medium				Low			
a) Adults freshwater												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River basin[a,b]												
Upper Sacramento River spawning[c]												
b) Juvenile emigration												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River at Red Bluff [d]												
Sacramento River at Knights Landing[e]												
Sacramento trawl at Sherwood Harbor[f]												
Midwater trawl at Chipps Island[g]												

Sources: [a] (Yoshiyama et al. 1998); (Yoshiyama et al. 1998, Moyle 2002b); (Moyle 2002b); [b](Myers et al. 1998) ; [c] (Williams 2006) ; [d] (Martin et al. 2001); [e] Knights Landing Rotary Screw Trap Data, CDFW (1999-2011); [f,g] Delta Juvenile Fish Monitoring Program, USFWS (1995-2012)

More detailed information is available for winter-run Chinook salmon presence at the location of the NDD intake construction. A small proportion (approximately two percent) of outmigrating juvenile winter-run Chinook salmon may enter the upper reaches of the Delta starting in October (U.S. Fish and Wildlife Service), although the entry timing is highly correlated with the first high flows of the migration season. December to February is the peak of juvenile winter-run Chinook salmon presence at the NDD intake location (del Rosario et al. 2013). After a brief period of rearing, most juvenile winter-run will exit the Delta in March and April (del Rosario, et al. 2013, Pyper, et al. 2013). Adult winter-run Chinook salmon enter the San Francisco Bay from November to June (Hallock and Fisher 1985), migrating up the Sacramento River past the Red Bluff Diversion Dam (RBDD) from mid-December to early August (NMFS1997). The majority of the run passes RBDD between January and May, with a peak in mid-March (Hallock and Fisher 1985).

The Sacramento River is the primary migration route for both juvenile and adult winter-run Chinook salmon to enter and leave the northern Delta. In certain hydrologic conditions, however, fish may pass over the Fremont Weir into the Yolo Bypass or toe drain, which provides an alternative migratory route for both downstream outmigrating juveniles and upstream adult migrants. High river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter in response to heavy precipitation events, but not in every year. Fish migrating via the Sacramento River or over the Fremont Weir will converge in the Sacramento River at the confluence of Cache Slough, Steamboat Slough, and the main stem Sacramento River for access to the estuary.

Pile-driving activities at the NDD intake locations have the potential to affect both juvenile and adult winter-run Chinook salmon, though exposure is expected to be minimized. Approximately two percent of the winter-run-sized juvenile Chinook occur at the NDD intake location as early migrants. Juvenile winter-run Chinook salmon typically complete their outmigration by March or April. Because all pile driving at the NDD intake locations is expected to be completed during the proposed in-water work window of June 1 through October 31, approximately two percent of the population is expected to be exposed to the pile-driving-induced noise. Adult winter-run Chinook salmon are not expected to be present at the NDD intake locations during pile-driving activities. Because the large majority passes the NDD intake location by May, their presence after June 1 is highly unlikely. Exposure of winter-run Chinook salmon to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at the NDD intake locations is proposed to last five years (2022 through 2026), potentially exposing several year classes to pile-driving effects.

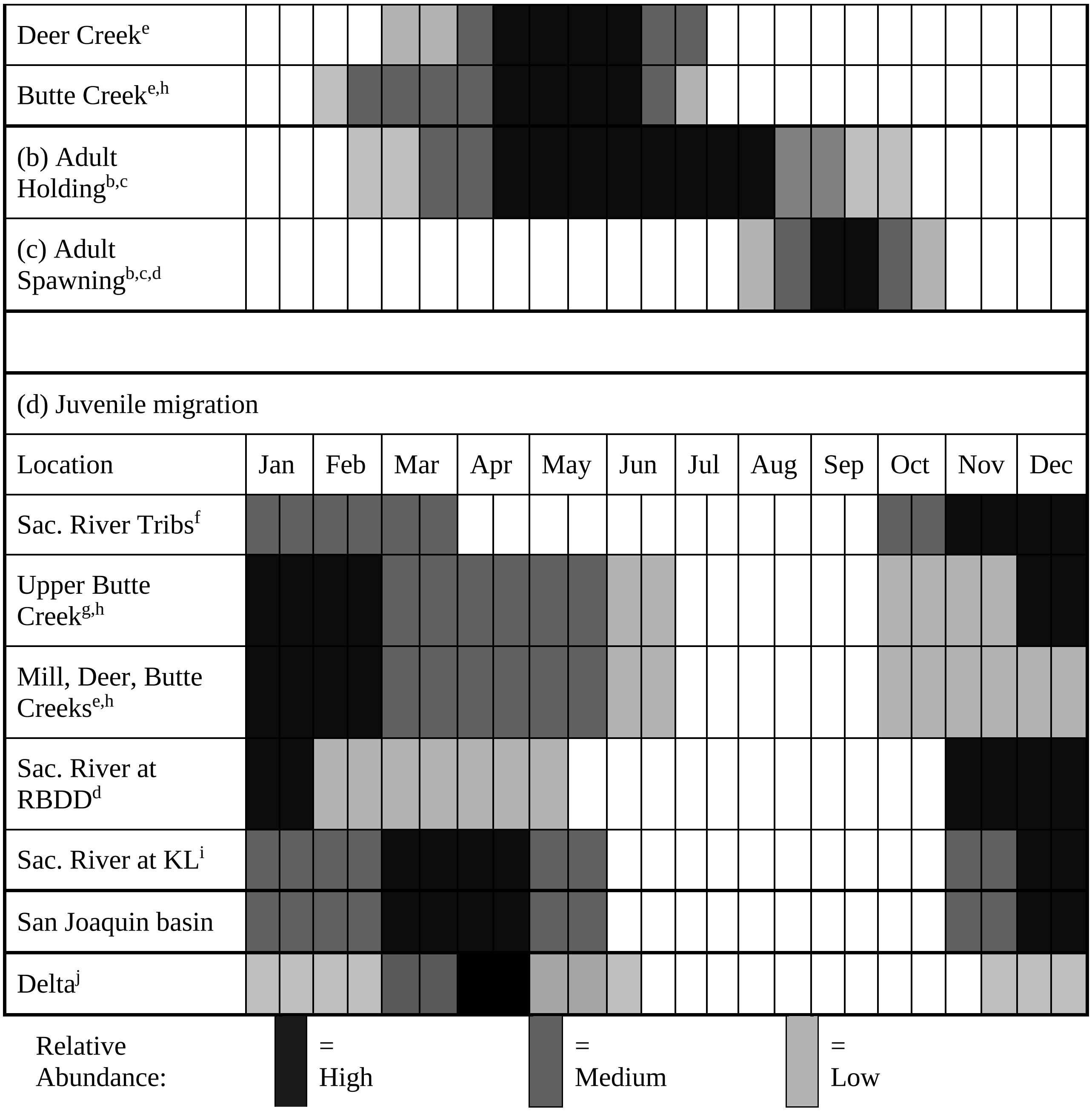
Given the extended construction period and the timing of juvenile and adult winter-run presence, NMFS therefore expects that the noise generated by pile-driving activities at the NDD intake locations will adversely affect a small proportion of juvenile winter-run Chinook salmon.

2.5.1.1.1.1.1.2 Spring-run Exposure and Risk

The life history and spatial and temporal presence of spring-run Chinook salmon is described in *Section 2.4.2 Environmental Baseline* general presence in the Sacramento River and Delta is shown in Table 3-5, which includes adult (a) and juvenile (b) spring-run in the Sacramento River and Delta. Darker shades indicate months of greatest relative abundance.

Table 3-5. The temporal occurrence of adult (a) and juvenile (b) Central Valley spring-run Chinook salmon in the Sacramento River

(a) Adult migration												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Delta[a]												
San Joaquin basin												
Sac. River basin[b,c]												
Sac. River Mainstem[c,d]												
Mill Creek[e]												



Sources: [a]CDFG (1998) [b]Yoshiyama et al. (1998); [c]Moyle (2002); [d]Myers *et al.* (1998); [e]Lindley et al. (2004); [f]CDFG (1998); [g]McReynolds et al. (2007); [h]Ward et al. (2003); [i]Snider and Titus (2000); [j]SacTrawl (2015)

Note: Yearling spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Most young-of-the-year spring-run Chinook salmon emigrate during the first spring after they hatch.

More detailed information is available for spring-run Chinook salmon presence at the location of the NDD intake construction. Outmigrating juvenile spring-run Chinook salmon will enter the upper reaches of the Delta starting in November and continuing through May or June (DJFMP). Only five percent of spring-run sized juvenile Chinook salmon are found near the NDD intake location in May and less than one percent in June (DJFMP). February to April is the peak of juvenile spring-run Chinook salmon presence at the NDD intake location, with the overwhelming majority (52 percent) of spring-run-sized fish entering the Delta in April. Although a few remaining fish may still be migrating through the Delta in early June in some years, juvenile spring-run Chinook salmon typically spend very little time rearing in the Delta. Most juveniles are large, actively migrating smolts that have been shown to move rapidly through the Delta and estuary during their seaward migration (Williams 2006).

Adult spring-run Chinook salmon enter the San Francisco Bay from late January to early February (California Department of Fish and Game 1998) and enter the Sacramento River in March (Yoshiyama et al. 1998), although adults may travel to tributaries as late as July (Lindley et al. 2004). Spring-run Chinook salmon adults will hold during the summer either far upstream or in cool water refugia before emerging to spawn in September to October (Moyle 2002a). The observed patterns of adult immigration into Mill Creek indicates that adult spring-run Chinook salmon will be well upstream of the Delta during June through October.

As with winter-run Chinook salmon, the Sacramento River is the primary migration route for both juvenile and adult spring-run Chinook salmon to enter and leave the northern Delta. Because high river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter, but not in every year, most juvenile and adult spring-run Chinook salmon will pass the NDD intake location.

Because all pile driving at the NDD intake locations is expected to be completed during the proposed in-water work window of June 1 through October 31, there is a reduced likelihood that any juvenile spring-run Chinook salmon will be exposed to the effects of pile-driving-induced noise. Recent monitoring data, however, show that a few juvenile spring-run sized Chinook salmon have been found at the NDD intake location after May (DJFMP). NMFS therefore expects that the noise generated by pile-driving activities at the NDD intake locations would adversely affect a small proportion of juvenile spring-run Chinook salmon.

Adult spring-run Chinook salmon are not expected to be present at the NDD intake locations during pile-driving activities. Because the large majority of adult spring-run Chinook salmon pass the NDD intake locations earlier in the year and are observed immigrating into natal streams from April through June, their presence at the NDD intake location after June 1 is highly unlikely. NMFS therefore expects that the noise generated by pile driving at the NDD intake locations would not adversely affect adult spring-run Chinook salmon.

2.5.1.1.1.1.1.3 Steelhead Exposure and Risk

The life history and spatial and temporal presence of California Central Valley steelhead is described in section ***Error! Reference source not found.*** **Error! Reference source not found.**. Table 3-6 below (from Appendix XX) shows the temporal occurrence of (a) adult and (b) juvenile California Central Valley steelhead at locations in the Central Valley. Darker shades indicate months of greatest relative abundance.

This document is in draft form, for the purposes of soliciting feedback from independent peer review.

Table 3-6. The temporal occurrence of (a) adult and (b) juvenile California Central Valley steelhead at locations in the Central Valley.

(a) Adult migration												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[1]Sacramento R. at Fremont Weir												
[2]Sacramento R. at RBDD												
[3]Mill & Deer Creeks												
[4]Mill Creek at Clough Dam												
[5]San Joaquin River												
(b) Juvenile migration												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[1,2]Sacramento R. near Fremont Weir												
[6]Sacramento R. at Knights Landing												
[7]Mill & Deer Creeks (silvery parr/smolts)												
[7]Mill & Deer Creeks (fry/parr)												
[8]Chipps Island (clipped)												
[8]ChippsIsland (unclipped)												
[9]San Joaquin R. at Mossdale												
[10]Mokelumne R. (silvery parr/smolts)												
[10]Mokelumne R. (fry/parr)												
[11]Stanislaus R. at Caswell												
[12]Sacramento R. at Hood												

Relative Abundance: = High = Medium = Low

Juvenile steelhead are present in the Delta throughout the year, as indicated by monitoring results at Chipps Island (USFWS) and CVP/SWP salvage data, but the emigration period may depend on origin. Hatchery smolts are present from January through March, with the peak occurring in February and March. Wild steelhead outmigration also peaks in February and March, but is spread over a longer period, lasting from fall or early winter through early summer. Wild fish that are present in the Delta late in the season may be from the San Joaquin River system rather than the Sacramento River basin, based on the proximity of the basin to the pumps and the April-May timing of tributary spring pulse flows.

At the NDD intake locations, steelhead smolts typically appear by November and continue into June (Table 3-6), based on CVP/SWP salvage data. Presence increases through December and January (22 percent of average annual salvage), peaks in February (37 percent) and March (31 percent), and declines in April (8 percent). By June, steelhead smolt outmigration through the Delta has essentially ended. Adult steelhead start to enter the Delta region as early as June, with approximately 12 percent in August, 44 percent in September, 24 percent in October, and 7 percent in November. Low levels of adult CCV steelhead continued to emigrate upriver through March.

As with Chinook salmon, the Sacramento River is the primary migration route for both juvenile and adult CCV steelhead from the Sacramento River basin to enter or leave the northern Delta. High river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter and can provide access to a large number of steelhead in some years, but the majority of juvenile and adult steelhead are typically assumed to pass the NDD intake location.

Pile-driving activities at the NDD intake locations may potentially affect both juvenile and adult steelhead, though to differing extents. Approximately one to two percent of the emigrating juvenile CCV steelhead population will be exposed to the effects of pile-driving-induced noise during the June 1 to October 31 in-water work window. Most of this exposure will occur in either the beginning or the end of the work window. There is little probability of exposure of juvenile CCV steelhead to pile-driving-induced noise during the summer months of July and August.

Despite the in-water work window, a much greater proportion of the adult population of CCV steelhead will be exposed to pile-driving activities at the NDD intake locations. Approximately 80 percent of the annual adult upstream migration occurs within the June through October window. The peak upstream movement of adult fish occurs in September and October (69 percent of annual escapement). NMFS therefore expects a substantial proportion of the adult CCV steelhead to be exposed to pile-driving activities at NDD intake locations.

The exposure of CCV steelhead to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at the NDD intake locations is proposed to last five years (2022 through 2026). Therefore, at least six different year classes could potentially be exposed to pile-driving effects. Though active in-water work is expected to be limited to a single intake location in most years, the PA proposes at least one year (2025) during which work will occur simultaneously at adjacent intake locations (Intakes 2 and 3). Because these intakes are separated by only 0.7 river miles, the extent of the sound field generated by pile-driving activities is expected to overlap and cover several miles. Therefore, the risk of exposure to CCV steelhead is increased due to multiple years of exposure and overlap of effects of activities in close proximity to each other.

Exposure of CCV steelhead to the adverse acoustics effects is related to the timing of steelhead presence at the NDD intake locations. The expected annual duration for the insertion of 2,500 sheet piles is 42 days. This is approximately 27.5 percent of the days from June through October for continuous pile driving (7 days per week) and approximately 38 percent for pile driving limited to weekdays. The installation of foundation piles is expected to take 14–19 days depending on intake, which is 9 to 12 percent of the work window period.

Only steelhead from the Sacramento River basin are expected to be present at the NDD intake locations during the work window because adult steelhead from the San Joaquin River basin are not expected to be moving upriver into the Sacramento River. Monitoring on the Sacramento River shows that few juvenile CCV steelhead would be expected to be present in the June through October period (less than or equal to one percent annual catch).

In contrast, approximately 83 percent of the adult CCV steelhead population from the Sacramento River basin is expected to be migrating upstream and past the NDD intake locations during the in-water work period of June through October. Because a smaller proportion of the population (approximately two percent) migrates past the NDD intake locations in June and July, if pile driving occurs during those earlier months of the in-water work window, then a minimal proportion of the adult population is at risk of exposure to effects. Conversely, if pile driving is delayed until later in the work window, especially during September and October, then a much greater proportion of the population is at risk of adverse effects.

Given that the exact timing of pile driving activity is not yet determined and there is potential for a high proportion of the adult CCV steelhead population from the Sacramento River basin to be repeatedly exposed to pile-driving activities over several years, NMFS expects that the acoustic effects of construction-related pile driving at the NDD intake locations will adversely affect a large proportion of CCV steelhead each year of the construction period.

2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk

Because of sparse monitoring data for juvenile, sub-adult, and adult life stages in the Sacramento River and Delta, there are significant data gaps to describing the presence of this species at the NDD intake location.

The life history and spatial and temporal presence of sDPS green sturgeon is described in section *2.4.3 Environmental Baselin*e. Young green sturgeon are believed to rear for the first one to two months in the Sacramento River (California Department of Fish and Game 2002) before migrating downstream in the first two to three years (Nakamoto et al. 1995). CVP/SWP salvage data show that green sturgeon are present in the Delta throughout the year, and mostly as juveniles or subadults. The lack of any juveniles smaller than approximately 200 millimeters in the Delta suggests that younger individuals rear in the Sacramento River or its tributaries. Juvenile sDPS green sturgeon may even hold in the mainstem Sacramento River for up to 10 months, as suggested by Kynard et al. (2005). While juvenile sDPS green sturgeon may be present in the Delta during any month of the year (California Department of Fish and Game 2002), the species appears to be most prevalent during July and August and as juveniles or sub-adults. It is believed that juveniles use the Delta for rearing for a period of approximately three years because the majority of juveniles that were captured in the Delta were between two to three years old based on age/growth studies (Nakamoto et al. 1995).

Given that the exact timing of pile driving activity is not yet determined and there is potential for juveniles and sub-adult green sturgeon to be present year-round at the NDD intake locations and experience multiple years of exposure to the pile-driving activities, NMFS expects that the acoustic effects of construction-related pile driving at the NDD intake locations will adversely affect a small proportion of juvenile and sub-adult green sturgeon each year of the construction period.

2.5.1.1.1.1.1.5 Fall/Late Fall-run Exposure and Risk

Fall-run Chinook Salmon

Juvenile fall-run Chinook salmon are present at the NDD intake locations from December through August, based on Sacramento trawl data for RM 55. These fish would likely be smaller sub-yearlings that may migrate more slowly than large smolts (such as outmigrating spring-run Chinook salmon). Adult fall-run Chinook salmon enter the San Francisco Bay starting in June and immigrate past the NDD intake locations between July and December (Vogel and Marine 1991), with a peak in October.

As with other salmonids, the Sacramento River is the primary migration route for both juvenile and adult fall-run Chinook salmon to enter and leave the northern Delta. Because high river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter, but not in every year, most juvenile and adult fall-run Chinook salmon will pass the NDD intake location.

Pile-driving activities at NDD intake locations are likely to affect juvenile and adult fall-run Chinook salmon, though to different extents. Juvenile presence during the work window would be limited to June through August, which represents a period of lowest occurrence of fall-run Chinook salmon juveniles in the Sacramento trawl. Because pile-driving activities at the NDD intake sites is expected to occur through October 31, however, adult fall-run Chinook salmon would be exposed to acoustics effects during the peak migration month of October. The exposure of fall-run Chinook salmon to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at NDD intake locations is proposed to last five years (2022 through 2026), potentially exposing several year classes to pile-driving effects.

Given the extended construction period and the timing of juvenile and adult fall-run presence, NMFS therefore expects that the noise generated by pile-driving activities at the NDD intake locations will adversely affect a small proportion of juvenile fall-run Chinook salmon and a large proportion of adult fall-run Chinook salmon.

Late Fall-run Chinook Salmon

Late fall-run Chinook salmon smolts migrate downstream from the Sacramento River through the Delta and Bay at a rate ranging from 11 to 22 miles day (Michel et al. 2015).

Juvenile late fall-run Chinook salmon are present at the NDD intake locations from July through January, peaking in December, based on Sacramento trawl data for RM 55. Adult late fall-run Chinook salmon enter the San Francisco Bay starting in September and immigrate past the NDD intake locations between the end of October through March (Vogel and Marine 1991).

As with other salmonids, the Sacramento River is the primary migration route for both juvenile and adult late fall-run Chinook salmon to enter and leave the northern Delta. Because high river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter, but not in every year, most juvenile and adult late fall-run Chinook salmon will pass the NDD intake location.

Pile-driving activities at NDD intake locations are likely to affect juvenile and adult late fall-run Chinook salmon, though to different extents. Juvenile presence during the work window would extend from July through September, potentially exposing juveniles to effects of pile driving for a three-month period. Adult late fall-run Chinook salmon, however, would not be exposed to the action except for October, the very beginning of the upstream migration period. The exposure of fall-run Chinook salmon to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at the NDD intake locations is proposed to last five years (2022 through 2026), potentially exposing several year classes to pile driving effects.

Therefore, given the extended construction period and the timing of juvenile and adult late fall-run presence, NMFS expects that the noise generated by pile-driving activities at the NDD intake locations will adversely affect a large proportion of juvenile late fall-run Chinook salmon and a small proportion of adult late fall-run Chinook salmon.

2.5.1.1.1.1.2 Clifton Court Forebay

The PA includes an expansion and modification to Clifton Court Forebay, an approximately 2,500-acre water body that serves as a storage reservoir for off-peak pumping by the SWP. As described in Chapter 3 of the BA and Appendix 3B and the September 28, 2016 memo from DWR, construction associated with expansion and modification of Clifton Court Forebay (CCF) is estimated to last eight years (2021 through 2028), with in-water construction occurring between 2023 and 2027. All in-water work, including pile driving, is expected to occur during the July 1 through November 30 work window in each construction year. The work will be phased according to:

- Phases 1 and 2: Expansion of south CCF (SCCF).
- Phase 3: Construction of the divider wall between north CCF (NCCF) and SCCF.
- Phases 4 and 5: Construction of the west and east embankments.
- Phase 6: Construction of the NCCF east, west, and north side embankments.
- Construction of the siphon between the NCCF and the conveyance canals.

Therefore, actions that will require driving sheet piles include construction of:

- the channel between the new southern expansion area and the existing CCFB (Phase 2),
- the divider wall separating the existing CCF into northern and southern halves (Phase 3),
- a cofferdam on the eastern and western sides of the newly created SCCF to allow construction of new embankments (Phases 4 and 5), and
- two cofferdams to allow construction of the siphon between the newly created NCCF and the conveyance canals to the south.

The PA includes plans to install 5,125 sheet piles for the construction of embankment cofferdams, 5,169 sheet piles for the dividing wall across CCF, and 2,160 14-inch concrete or steel foundation piles for the NCCF siphon.

The PA does not specify the number of sheet piles to be used for construction of the cofferdam surrounding the NCCF siphon construction site or for construction of the sheet pile channel in the southern CCF embankment to allow flooding the newly constructed expansion cell of the SCCF. Specific activity durations, start dates, and end dates are show in Table 3-7, while locations of actions and details on pile type and driving details are in Table 3-8 and Table 3-9.

Table 3-7. Clifton Court Forebay Modification Specific Activity Durations, Start Dates, and End Dates

Task Name	Duration (days)	Start Date	End Date
NCCF installation of sheet piles for siphon (season 1)	109	7/3/23	11/30/23
NCCF installation of sheet piles for siphon (season 2)	109	7/1/24	11/28/24
Construct SCCF earthen embankment	500	7/7/23	6/5/25
Install sheet pile channel in southern embankment	30	7/1/25	8/11/25
SCCF remove existing southern dike	200	6/6/25	3/11/26
Install Action 1 sheet piles for CCF dividing wall	109	7/1/25	11/28/25
Install Action 2 sheet piles to close partition sheet piles	30	7/1/26	8/11/26
SCCF installation of sheet piles for east and west embankments	109	7/1/27	11/30/27

Table 3-8. Pile Driving Activity Details for Clifton Court Forebay Modification

Clifton Court Forebay										
Facility/ Structure	Location	Lat/long	On land (distance to water in ft) or in water	River depth (ft)[1]	River width (ft)	Width of in-river construction (ft)	Length of construction along river bank (ft)	Proportion of river available for passage	Straight line distance to river bend (furthest upstream or downstream location) (ft)	Distance to concurrent pile driving sites (ft)[2]
Embankment cofferdams	CCF	37.83204, -121.57494	In water	-3	10,500 (width of CCF)	25	20,800	NA	NA	Unknown
Divider wall	CCF	37.83961, -121.57514	In water	-3	10,500 (width of CCF)	<5 percent of total surface area of CCF	9,800	NA	NA	Unknown
NCCF siphon	CCF	37.83257, -121.59218	In cofferdam 20-30 feet from open water	-17	600 (width of entrance channel)	300	150	50 percent	NA	300

Table 3-9. Physical Data for Pilings at Clifton Court Forebay

Clifton Court Forebay–Physical Data for Pilings								
Structure	Pile Type/Sizes	Total Piles per site	# of concurrent pile drivers per site	Piles per day	Strikes per pile (impact driving only)	Total strikes per day	Sound Attenuation Devices	Expected acoustic dampening in dB
Embankment cofferdams	Sheet piles (AZ-28-700)	5,125	4	60	210[1]	12,600	None	NA
Divider wall	Sheet piles (AZ-28-700)	5,169	4	60	210	12,600	None	NA
NCCF Siphon	14-inch concrete or steel piles	2,160	2	30	1,050	31,500	Dewatering or bubble curtains, if feasible/practicable	5 dB
Notes [1] Assumes 70 percent of pile can be driven using vibratory driving followed by impact driving to drive the remainder of the pile. General: All assumptions will be refined as part of next engineering phase when site-specific geotechnical data are collected.								

Table 3-10 presents the extent, timing, and duration of pile-driving noise levels predicted to exceed the interim injury and behavioral thresholds at the CCF based on application of the NMFS spreadsheet model and the assumptions presented in *Appendix 3.E Pile Driving Assumptions for the Proposed Action* (excerpted from Table 3.E-1 and 3.E.2.). During sheet pile installation, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 3-10. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the CCF Site

Clifton Court Forebay						
Facility	**Distance to 206-dB SPL Injury Threshold (feet)**	**Distance to Cumulative 187-dB SEL Injury Threshold[1,2], (feet)**	**Distance to 150-dB RMS Behavioral Threshold[2] (feet)**	**Number of Construction Seasons**	**Timing of Pile Driving**	**Duration of Pile Driving (days)**
Embankment cofferdams	30	2,814	13,058	1 (Year 6)	Jul-Nov	85
Divider wall	30	2,814	13,058	1 (Year 4 and 5)	Jul-Nov	86
NCCF siphon (no attenuation)	46	1,774	9,607	2 (Years 2 and 3)	Jul-Nov	72
NCCF siphon (with attenuation)	20	823	4,458	2 (Years 2 and 3)	Jul-Nov	72

[1] Computed distances to injury thresholds are governed by the distance to "effective quiet" (150-dB SEL). . Calculation assumes that single strike SELs <150-dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance.

[2] Distance to injury and behavioral thresholds assume an attenuation rate of 4.5-dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the

Clifton Court Forebay currently is an approximately 2,500-acre water body that serves as a storage reservoir for off-peak pumping by the SWP. It is approximately 2.5 miles long by 2.0 miles wide with an average depth of 6.5 feet.

NCCF Siphon. As proposed in the PA, pile driving at the NCCF siphon site will create substantial adverse acoustic conditions to exposed fish in CCF. Pile driving for the NCCF siphon will occur adjacent to the inlet channel to the Skinner Fish Protection Facility on the western side of the forebay and will occur in years 2 and 3 of the construction schedule (Table 3-10). The width of the opening from the forebay to the inlet channel is approximately 600 feet. The width of the forebay from the inlet channel opening to the opposite shoreline (due east) is approximately 10,800 feet. The proposed cofferdam will occupy one half of the inlet channel, leaving a channel 300-feet wide.

After the first construction season, the cofferdam will be constructed on the opposite side of the inlet opening, the previous cofferdam removed, and the remainder of the siphon completed. As described in Appendix 3.E of the BA, the calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet, or approximately five percent of the 600-foot channel width when measured from the levee edge, or maximum of 10 percent when the sheet piles are being driven mid-channel (30 feet of the remaining 300-foot passage channel to the adjacent levee). The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,814 feet. This completely encompasses the entire inlet channel width at the siphon location and extends the zone of injury for one day's pile driving activity the same distance out into CCF. The distance to the 187-dB SEL threshold is approximately 26 percent of the distance across the forebay. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving of the siphon cofferdam will extend across the entire width of the forebay to the opposite shore and encompass the entire water body of CCF because the distance to any shoreline on the opposite side of the forebay is less than 13,000 feet.

The BA states that thirty 14-inch steel or concrete piles will be driven each day to construct the foundation of the siphons (BA Appendix 3.E). Pile driving associated with installing the NCC siphon foundation piles is calculated to have a 206-dB SPL threshold distance of 46 feet (7.7 percent of the 600-foot-wide inlet channel opening) and 20 feet (3.3 percent of the channel opening) with a 5-dB reduction due to attenuation practices. If the piles are being driven in a mid-channel location, the percentage of the channel blocked is doubled. The calculated distance to the 187-dB SEL cumulative injury threshold without any attenuation devices is 1,774 feet; 823 feet with a 5-dB attenuation device. Under attenuated and unattenuated conditions, the entire inlet channel will exceed the 187-dB SEL threshold. The distance to the 187-dB threshold for unattenuated pile driving will extend approximately 16 percent of the width of the forebay and approximately 7.6 percent of the forebay width for attenuated conditions. The calculated distance to the 150-dB RMS threshold for behavioral effects is 9,607 feet. Therefore, discernable impacts (behavioral modification) from pile driving the siphon foundation piles will extend almost completely across the entire width of the forebay to the opposite shore (approximately 90 percent), which leaves approximately a 1,000-foot buffer around the perimeter of the entire water body of CCF.

Adverse effects related to the acoustic conditions created by the pile driving will occur over two consecutive years at the siphon location (2023 and 2024). NMFS anticipates it will take approximately 12 days to drive the 350 sheet piles (approximately 750 lineal feet of cofferdam) associated with each cofferdam per work season, driving 30 piles per day with two pile drivers operating concurrently. Driving the foundation piles is expected to take an additional 72 days. NMFS anticipates that pile driving will last at least 85 days and as long as 109 days each in-water work season, as described in the work schedule (BA Appendix 3D).

Sheet Pile Channel in Southern Embankment

Pile driving associated with construction of the southern embankment channel is expected to create adverse acoustic conditions in the surrounding waters of CCF, which may result in the injury or death of exposed fish. Pile driving for the channel that will allow flooding the expanded southern CCF on Byron Tract will occur on the southwestern end of the currently existing earthen embankment during the in-water work window in 2025 and will last 30 days (Table 2-6). The width of the forebay from the channel location to the farthest opposite side of the forebay (northern side) is approximately 13,200 feet. The proposed cofferdam channel will pierce the earthen southern embankment, leaving a channel 60-feet wide when completed. The cofferdam channel will require driving sheet pile walls on both sides of the channel, approximately 200 feet long, and driving end walls at the end of the channel. A temporary 60-foot-wide sheet pile end wall will be constructed to block flow from the current forebay into the new southern cell of the forebay on Byron Tract. This temporary wall will be pulled to allow controlled flooding of the new southern forebay cell when it is ready.

Following removal of the existing earthen embankment on the southern side of CCF, the sheet pile channel will be removed. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet, or approximately 0.2 percent of the 13,200-foot width of the existing forebay. The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,814 feet. This extends the zone of injury for one day's pile driving activity the same distance out into CCF. The distance to the 187-dB SEL threshold is approximately 21 percent of the distance across the forebay. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving of the channel cofferdam will extend across the entire width of the forebay to the opposite shore and encompass the entire water body of CCF because the farthest distance to the shoreline on the opposite side of the forebay is just slightly greater than 13,000 feet.

This will be the initial case. Concurrent with the installation of the channel through the southern embankment, however, the cross forebay partition cofferdam separating the northern and southern halves of the forebay will be constructed. As the cofferdam partition wall is constructed, the straight line path across the forebay will be altered by the lengthening sections of the dividing wall, which should partially block the transmission of sound through the forebay creating a more complex sound field in the forebay. The closet point of the partition wall to the southern embankment channel is approximately 5,000 feet. Therefore, there is the potential that overlapping fields of sound during construction of the channel and the forebay partition wall will create a field of sound that exceeds the 187-dB SEL threshold across the western half of the forebay during the month of July 2025 when construction periods overlap. This will expose any fish present to levels of sound that may result in injury or death.

Adverse effects related to the acoustic conditions created by pile driving for this element of the PA will occur in only one year of construction (currently scheduled for 2025) and pile driving is not scheduled to last more than 30 days within the in-water work period (July 1 to August 11, 2025). The distance to the 187-dB SEL threshold will not extend to the inlet channel opening at the western end of CCF, and thus is not expected to cause injury to fish entering the inlet channel leading to the Skinner Fish Salvage Facility.

CCF Partition Dike (Cofferdam Wall)

Adverse acoustic effects are expected to result from pile driving sheet piles associated with the partition dike element of the PA. Construction of the partition dike will allow for separating the current CCF water body into a northern and southern half.

Following completion of the partition dike, the northern side of the forebay (now called NCCF) will be dewatered and construction allowed to continue in the dry for the remaining actions, including excavating the forebay to the design depth, building the earthen embankments across the forebay and around the perimeter of the NCCF, and constructing the spillway and CCF pumping plants.

Once the earthen embankment is constructed behind the partition dike, the dike will be removed or cut off at the mud line. The project description for the PA describes the partition dike as approximately 10,500 feet long, spanning the entire width of the CCF, and will require 5,169 sheet piles to complete. It is anticipated that using four pile drivers, operating concurrently, 60 sheet piles per day can be installed, requiring 86 days, but perhaps as long as 109 days, to complete the first phase of the partition dike installation. The proposed in-water work window is from July 1 to November 30 and will overlap with portions of adult migrations of CCV steelhead from both the Sacramento and San Joaquin river basins as described above.

As described in the September 28, 2016 memo to NMFS, the entire partition dike will be installed in the first season of work, except for two, 100-foot wide gaps on the eastern and western ends of the dike to allow water to flow between the two halves. The partition dike will be installed during the same in-water work season as the channel in the southern embankment (2025). The following work season (2026), the two gaps will be closed with sheet piles, isolating the northern portion of CCF from the southern CCF during the in-water work window. It is anticipated that this will take 30 days within July 1 to August 11, 2026.

Based on the proposed alignment of the partition dike from east to west across the CCF, the northern perimeter of the forebay is no more than 6,800 feet from the partition dike alignment. The southern current embankment is typically no more than 5,300 feet from the alignment. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet. Because the partition dike is surrounded on both sides by water, the width of the zone that exceeds 206-dB SPL is 60 feet or approximately 0.4 percent of the 13,200-foot width of the existing forebay.

The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,814 feet. This extends the zone of injury for one day's pile driving activity the same distance out into CCF on either side of the partition dike alignment (a band 5,628-feet wide). The distance to the 187-dB SEL threshold covers approximately 43 percent of the distance across the forebay on either side of the alignment. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet.

Therefore, discernable impacts (behavioral modification) from pile driving the partition dike cofferdam will extend across the entire width and length of the forebay because the farthest distance to the shoreline from the partition dike alignment is 6,800 feet, and four pile drivers will be operating concurrently along the alignment.

Adverse effects related to the acoustic conditions created by the pile driving for this element of the PA will occur in two different years of construction (2025 and 2026). In the first year of construction, adverse acoustic effects may occur over a period of 5 months (July through November), with an estimated maximum of 109 days of pile driving. In the second year of construction, it is estimated that only 30 days will be needed to close the two gaps in the partition dike, which will occur during July 2026.

Alignment of the partition dike will act as a guidance barrier leading fish across the CCF towards the inlet to the intake channel and the Skinner Fish Protection Facility. Pile driving will form a band of sound along the entire length of the partition dike alignment from the eastern perimeter of CCF to the inlet channel on the western side of the forebay that will exceed the 187-dB SEL threshold. Thus, it is expected that injury to fish will occur as they follow the partition dike to the inlet channel.

Embankment Cofferdams

Adverse acoustic effects are expected to result from pile driving sheet piles associated with the construction of cofferdams around the perimeter of CCF to allow for constructing earthen embankments behind them. These cofferdams will be situated on the eastern and western sides of the current CCF. On the eastern side of CCF, the cofferdams will extend from the location of the current radial gates and forebay inlet to the location of the partition dike. On the western side of CCF, the cofferdams will extend from the current location of the southern embankment to the inlet to the intake channel where the NCCF siphon will be constructed. The combined length of the cofferdams is approximately 11,000 linear feet, requiring 5,125 sheet piles to construct. The project description for the PA indicates that four pile drivers will be operated concurrently to install the sheet piles, installing 60 piles per day. Installation of the piles will take 85 days over the 109-day in-water work window in 2027 (July 1 through November 30).

Based on the proposed location of the embankment cofferdams, the farthest distance to the opposite shore of CCF is 12,600 feet from the western cofferdam to the northeastern corner of CCF and approximately 11,000 feet from the eastern cofferdam adjacent to the radial gates to the northern edge of CCF. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet. The width of the zone that exceeds 206-dB SPL is 30 feet or approximately 0.2 percent of the 12,600-foot width of the existing forebay. This is doubled, however, because cofferdams are being installed on both the eastern and western sides of CCF simultaneously.

The distance to the 187-dB SEL cumulative injury threshold for one day’s piling driving activity is calculated as 2,814 feet. This extends the zone of injury for one day’s pile driving activity the same distance out into CCF from the shoreline location of the cofferdams. The distance to the 187-dB SEL threshold covers approximately 44 percent of the distance across the forebay when both cofferdams are being installed concurrently on the eastern and western sides of the forebay.

The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving embankment cofferdams will extend across the entire width and length of the forebay because the farthest distance to the opposite shoreline is 12,600 feet, and both the eastern and western sides of this construction element will operate concurrently.

Adverse effects related to the acoustic conditions created by pile driving for this element of the PA will occur in one year of construction (2027) over a period of five months (July through November), with an estimated maximum of 109 days of pile driving. The eastern and western sides of the forebay will have areas where acoustic effects from pile driving will exceed the 187-dB SEL threshold. Thus, it is expected that injury to fish will occur as they enter the forebay from the radial gates or exit the forebay as they enter the western inlet to the intake channel.

2.5.1.1.1.1.2.1 Chinook Salmon Exposure and Risk

The CCF is not along the natural migration routes of any of the Central Valley Chinook salmon species. Continued operation of CCF throughout the construction period, however, increases the risk of exposing listed fish species to adverse acoustic effects from pile driving.

Based on salvage collected from the Tracy Fish Collection Facility and the Skinner Fish Protective Facility, juvenile winter-run sized fish are typically in or near the CCF from December through April. Spring-run sized fish are expected to be in CCF from February through June, and the overwhelming majority (greater than 99 percent) of juvenile fall-run and late fall-run sized fish is present from January through June.

Adult fall-run Chinook salmon will migrate through the action area from July through December. Although all adult fall-run Chinook returning to spawn may potentially be found in the vicinity of CCF, those fish migrating to the Stanislaus River in the San Joaquin River basin are most likely to pass the CCF construction site and be subject to pile-driving-induced acoustic effects. The adult fall-run population is somewhat insulated from these effects because only about one percent of Central Valley fall-run spawn in the San Joaquin River basin (Hannon 2009).

Limiting pile-driving activities at CCF to the July 1 through November 30 work window is expected to minimize exposure to Chinook salmonid species because

- Juvenile winter-run Chinook salmon are expected to be present in CCF from December to April. Adult winter-run are present in the Delta between November and June, but are unlikely to be found in CCF because it is outside of their main upstream migratory route.
- Juvenile spring-run Chinook salmon are expected to be present in CCF from February to June, while adult spring-run are present in the Delta between January and March.
- Juvenile fall- and late fall-run Chinook salmon are expected to be present in CCF from January through June, with a small proportion of the run present during July to December. Although adult fall-run will be migrating through the action area from July through December, only a small proportion of the Central Valley population is expected to pass near CCF.

Given the timing of in-water construction activities, NMFS expects that the acoustics effects of pile driving in CCF will not adversely affect winter-run or spring-run Chinook salmon. Although the in-water work window will greatly reduce the exposure of juvenile fall-run and late fall-run Chinook salmon to pile-driving-induced acoustic effects, NMFS expects a small proportion of juvenile fall-run and late fall-run will be adversely affected. Adult fall-run, particularly the segment of the population spawning in the Stanislaus River, will be adversely affected by pile-driving-induced acoustics at the CCF construction site.

2.5.1.1.1.1.2.2 Steelhead Exposure and Risk

CCV steelhead are expected to be present in CCF during construction activities. It is expected that Old River will be accessible to CCV steelhead juveniles from the Sacramento River basin via an open DCC gate, providing exposure to the forebay. Old River will also be accessible to San Joaquin River basin fish emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries. The likelihood of fish from the Sacramento River being present, however, diminishes with distance from the main stem of the San Joaquin River. Less than one percent of the annual juvenile emigration is expected to occur during the proposed work window of July through November. Most juvenile steelhead presence in the CCF location will occur from December through March, based on CVP/SWP salvage data. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location, but in lower abundance than for fish originating in the Sacramento River basin.

It is expected that the timing of adult steelhead presence at CCF will be later than that observed for the north Delta. This is due to the southern Delta location of CCF and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January based on data from the Stanislaus River fish weir. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through November with the proposed in-water work window.

CCF is accessible to both adult and juvenile CCV steelhead from the Sacramento River, the eastside tributaries, and the San Joaquin River systems. Sacramento River fish access the site via opened DCC gates during the in-water work window. This allows for free movement of fish between the Sacramento River system and the Mokelumne River system, which feeds into the San Joaquin River. Access to the lower Mokelumne River is also available to Sacramento River basin fish via Georgiana Slough. Eastside tributaries feed into the Mokelumne River system or into the San Joaquin River near the Port of Stockton. Finally, San Joaquin River basin fish can access the site via the main stem San Joaquin through several distributaries, including Middle and Old rivers. Based on the location of CCF, it is expected that more San Joaquin River basin origin fish are likely to be present in the forebay construction site than Sacramento River basin fish during construction.

The CCF construction site may potentially expose CCV steelhead populations from the Sacramento River basin, eastside tributaries, and the San Joaquin River basin to the effects of pile driving during the in-water work window. For installation of sheet piles and steel foundation pilings for the NCCF siphons, less than one percent of the juvenile CCV steelhead population emigrating in a given year will be exposed to the effects of pile-driving-induced noise. There is little probability of exposure of juvenile CCV steelhead to pile-driving-induced noise during the summer months (July and August) of the in-water work window when water temperatures are typically elevated beyond the thermal tolerances of salmonids in the south Delta (greater than 72°F). The duration of the construction actions (five years, 2023-2027), however, will increase the risk of exposure over multiple years as opposed to actions lasting only a short time.

The in-water work window may potentially expose a much greater proportion of the adult population of CCV steelhead. Approximately 90 percent of the annual adult escapement to the Sacramento River basin will occur during the July through November in-water work window. The peak upstream movement of adult fish from the Sacramento River basin occurs in September and October (69 percent of annual escapement). The fraction of the Sacramento Basin population that migrates upstream through the San Joaquin River corridor and re-enters the Sacramento through either the Georgiana Slough corridor or via the open DCC gates could encounter the CCF construction site while staging to move upriver due to tidal movements in the main stem San Joaquin River and export-related alterations to the local hydraulics in the south Delta channels. This may induce fish to move south towards the CCF location.

The CCF inlet and radial gates are located on the Old River corridor, which is one of the potential migratory routes for adult San Joaquin River basin CCV steelhead. Because of this, a greater proportion of this basin's population is expected to migrate past this location than those from the Sacramento River basin.

Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta and San Joaquin basin tributaries starting in September, with most of the population passing through the Delta from November to January based on data from the Stanislaus River fish weir. Therefore, it is anticipated that an increasing risk of exposure for San Joaquin River basin adult CCV steelhead exists if the construction actions are delayed into October and November when upstream migration is increasing in the basin.

Given the proportion of the adult CCV steelhead population that could be exposed to pile-driving activities over several years, NMFS expects that the acoustic effects of construction-related pile driving at CCF will adversely affect a large number of individual adult CCV steelhead each year of the construction period, though this effect could be reduced by construction early in the work period.

2.5.1.1.1.1.2.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.4.3 Environmental Baseline*. Juvenile and sub-adult sDPS green sturgeon may be present during any month of the year throughout the waters of the Delta where they may spend extended periods of time foraging or sheltering, whereas adult green sturgeon are less widespread keeping primarily to the principal migration route through the waters of the north Delta on their way to and from upstream spawning habitats in the Sacramento River. Because of the widespread and year-round presence of juvenile and sub-adult life stages in the waters of the Delta, NMFS expects that these life stages of sDPS green sturgeon could be present in the south Delta and could, therefore, become exposed to the pile-driving-induced acoustic effects related to the expansion and modification of the Clifton Court Forebay during the July 1 through November 30 in-water construction period associated with that effort. Exposure is expected to be limited in number because the density of green sturgeon in the waters of the south Delta is minimal compared to the rest of the Delta and the Sacramento River in general.

2.5.1.1.1.1.3 HOR Gate

Construction of the HOR gate is expected to take two years and will include pile-driving activities. According to the preliminary design presented in the BA, the gate will be 210 feet long and 30 feet wide (BA *Appendix 3.C Conceptual Engineering Report, Volume 2*) and includes seven bottom-hinged gates, a fish passage structure, a boat lock, a control building, a boat lock operator’s building, and a communications antenna. According to BA *Appendix 3.D Construction Schedule for the Proposed Action*, the HOR gate will be constructed in two phases using sheet pile cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase. A sheet pile retaining wall will be installed in the levee where the operable barrier connects to it. All in-water construction work, including construction of cofferdams, sheet pile walls, and pile foundations, would be restricted to a work window of August 1through October 31 to minimize or avoid potential effects on listed fish species. All pile driving that requires using an impact pile driver in or near open water (cofferdams and foundation piles) will also be restricted to the in-water work period.

The BA presents estimated required piles for each component of the construction, including approximately 550 sheet piles (275 per season) for installing the cofferdams. Approximately 15 piles are expected to be set per day with an estimated 210 strikes per pile over a period of approximately 19 days per season. Sheet piles installation will begin with vibratory hammer; an impact hammer will be used if refusal is encountered before target depths. Installment of the foundation for the operable barrier will require 100 steel pipes or H-piles (50 per season) to be set with a single-pile driver on site. Approximately 15 piles are expected to be set per day with an estimated 1,050 strikes per pile over a period of approximately three days per season.

Foundation pile driving may be done in the dry or in the wet. Though cast-in-drilled-hole concrete foundation piles may be able to be used, the feasibility is currently unknown, and NMFS assumes use of impact driving.

Phase 1 (the first construction season) involves installing a cofferdam in half the channel and then dewatering that area (see section *3.2.10.7 Dewatering* of the BA). The cofferdam will remain in the water until completion of the first half of the gate. The cofferdam will then be flooded and removed or cut off at the required invert depth, and another cofferdam installed in the other half of the channel during phase 2 (second season). In this phase, the second half of the gate will be constructed using the same methods, with the cofferdam either removed or cut off upon completion of the gate.

In both phases, cofferdam construction will begin in August and last approximately 19 days. Construction has been designed so that the south Delta temporary barriers at this site can continue to be installed and removed as currently done until the permanent gates are fully operable. Installation and removal of the temporary barriers, however, is not part of the PA.

Table 3-11 and

Table 3-12 (from Tables 3.E-1 and 3.E-2 of the BA) describe the physical locations and details of pile-driving actions described for the construction of the HOR gate.

Table 3-11. HOR Gate Pile Driving Activity Details

HOR Gate										
Facility/ Structure	**Location**	**Lat/long**	**On land (distance to water in ft) or in water**	**River depth (ft)[1]**	**River width (ft)**	**Width of in-river construction (ft)**	**Length of construction along river bank (ft)**	**Proportion of river available for passage**	**Straight line distance to river bend (furthest upstream/ downstream location) (ft)**	**Distance to concurrent pile driving sites (ft)[2]**
HOR gate coffer dams	Old River 400 ft from SJR[2] junction	37.80798 -121.32912	In water	-6	150	75	50-100	50%	700-1,500	100

HOR gate found-ation	Old River 400 ft from SJR junction	37.80798, -121.32912	In cofferdam 20-30 feet from open water	-6	150	NA	30-80	NA	700-1,500	80

Table 3-12. Physical Data for Pilings at HOR Gate

HOR Gate–Physical Data for Pilings								
Structure	**Pile Type/Sizes**	**Total Piles per site**	**# of concurrent pile drivers per site**	**Piles per day**	**Strikes per pile (impact driving only)**	**Total strikes per day**	**Sound Attenuation Devices**	**Expected acoustic dampening in dB**
HOR gate cofferdams	Sheet piles (AZ-28-700)	550	1	15	210[1]	3,150	None	NA
HOR gate foundation	14-inch steel pipe or H-piles	100	1	15	1,050	15,750	None	NA

Notes

[1]Assumes 70 percent of pile can be driven using vibratory driving followed by impact driving to drive the remainder of the pile. General: All assumptions will be refined as part of next engineering phase when site-specific geotechnical data are collected.

[2]San Joaquin River = SJR

presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the HOR gate based on application of the NMFS spreadsheet model and the assumptions presented in *Appendix 3.E Pile Driving Assumptions for the Proposed Action* (excerpted from Table 3.E-1 and 3.E.2.). During installation of sheet piles, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 3-13 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the HOR gate based on application of the NMFS spreadsheet model and the assumptions presented in *Appendix 3.E Pile Driving Assumptions for the Proposed Action* (excerpted from Table 3.E-1 and 3.E.2.). During installation of sheet piles, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 3-13. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the HOR Gate Site

HOR Gate						
Facility	**Distance to 206-dB SPL Injury Threshold (feet)**	**Distance to Cumulative 187-dB SEL Injury Threshold[1,2], (feet)**	**Distance to 150-dB RMS Behavioral Threshold[2] (feet)**	**Number of Construction Seasons**	**Timing of Pile Driving**	**Duration of Pile Driving (days)**
HOR gate cofferdams	30	2,063	13,058	2 years	Aug 1-October 31	19
HOR gate foundation (no attenuation)	46	1,774	9,607	2 years	Aug 1-October 31	4
HOR gate foundation (with attenuation)	20	823	4,458	2 years	Aug-Nov	4

[1] Computed distances to injury thresholds are governed by the distance to "effective quiet" (150-dB SEL). Calculation assumes that single strike SELs <150-dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance.

[2] Distance to injury and behavioral thresholds assume an attenuation rate of 4.5-dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

The HOR gate location is approximately 400 feet downstream of the mouth of the divergence of Old River from the main stem of the San Joaquin River. At this location, the channel of Old River extends approximately 1,500 feet to the west before turning to the northwest. The Old River channel extends approximately 400 feet to the east to meet the San Joaquin River.

Based on the description provided, a single pile driver will be operating at this location for 19 days to drive sheet piles for the cofferdam during each of the two construction seasons. The pile driver is anticipated to drive 15 sheet piles per day with a cumulative total of 275 sheet piles per year over the two-year construction schedule. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet, or approximately 20 percent of the channel width of 150 feet when measured from the levee edge, or maximum of 40 percent when the sheet piles are being driven mid-channel (30 feet of the remaining 75-foot passage channel to the adjacent levee). The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,063 feet. This completely encompasses the entire river channel width at the HOR gate location and extends the zone of injury for one day's pile driving activity the same distance up and down the river channel from the construction location until the sound waves encounter the river banks approximately 1,500 feet to the west and 700 to 1,500 feet to the east (depending on which side of the channel pile driving is occurring on) which will attenuate the further propagation of the sound waves.

The estimated cumulative distance along the length of the river channel that exceeds the 187-dB SEL threshold is 1,500 feet to the west and 700 to 1,500 feet to the east. When pile driving occurs on the northern side of the Old River channel (season 2), then the farthest straight line distance to the east before encountering the opposite bank of the San Joaquin River is approximately 1,500 feet. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving of the HOR gate sheet piles will extend upstream and downstream of the gate site within the channel until the alignment of the channel is altered by bends in the river channel approximately 1500 to the west and 700-1500 feet to the east.

Exposure of CCV steelhead to the adverse acoustic environment is related to the timing of steelhead presence at the HOR gate location. The expected duration each year for the insertion of 275 sheet piles is 19 days. This amounts to approximately 61 percent of the days in each month (August through October) if pile driving is continuous (7 days per week) or approximately 80 percent if pile driving only occurs on weekdays and not over the weekend.

As stated previously, steelhead from the Sacramento River basin are not expected to be present at the HOR gate location. Adult steelhead from the San Joaquin River basin are not expected to be moving upriver in August, thus the potential for the presence of adult steelhead should be minimal during August. Upstream migration increases in September and October, increasing the risk of exposure. The peak upstream migration for San Joaquin River basin steelhead typically occurs from November through January, after the end of the in-water work window. Minimal exposure of juveniles from the San Joaquin River basin is expected during this time frame (less than one percent of annual juvenile steelhead salvage occurs during August through October). Therefore, exposure risk of adult steelhead from the San Joaquin River basin is greatest in October and least in August.

The adverse acoustic effects to the physiology of fish has a high level of certainty. The overlap with adult spawning migration timing for San Joaquin basin steelhead populations has a lower level of certainty, but is still fairly certain to be increasing from September through October.

Regarding pile driving of foundation pilings within the cofferdam, the expected distance to the 206-dB SPL is 46 feet without accounting for any attenuation of sound due to being behind the cofferdam or dewatering, or 20 feet if a conservative reduction of 5 dB is applied for sound attenuation resulting from dewatering of the space behind the cofferdam. This equates to approximately 31 percent of the channel width (150 feet) or 62 percent (if measured from the end of the cofferdam with only 75 feet of passage between the end of the cofferdam and the adjacent levee bank) for unattenuated sound, or 13 percent and 26 percent of the river channel for attenuated sound conditions.

The distance to the 187-dB SEL cumulative injury threshold for one day's unattenuated piling driving activity is calculated as 1,774 feet (823 feet attenuated). This completely encompasses the entire river channel width at the HOR gate location and extends the zone of injury for one day's pile driving activity the same distance up and down the river channel from the construction location until the sound waves encounter river banks.

For unattenuated pile driving conditions, the banks of the river channel will block further propagation of the sound waves up and down the channel length as described above. For the attenuated conditions, the distance to the 187-dB SEL level will not encounter the bend in the river to the west, but will partially encounter the river banks to the east, depending on which side of the river the piles are being driven (see above description). In any case, the junction of the San Joaquin River with Old River will fall within the area affected by the sound fields generated by pile driving. The distance to the 150-dB RMS behavioral modification threshold is calculated as 9,607 feet unattenuated, or 4,458 feet for attenuated conditions. As described above, bends in the river channel alignment will block the propagation of sound at shorter distances than these.

The expected duration each year for the insertion of 50, 14-inch steel pilings or H-piles is 4 days. This amounts to approximately 13 percent of the days in each month (August through October). It is anticipated that completion of the cofferdam installation, dewatering, and driving of foundation pilings will be accomplished within 30 days of starting the construction because these elements are considered to be sequential operations.

2.5.1.1.1.1.3.1 Chinook Salmon Exposure and Risk

The location of HOR gate is not along present-day migration routes of winter-run or late fall-run Chinook salmon. Fall-run and any spring-run Chinook salmon originating from, or migrating to, the San Joaquin River basin, however, would pass in close proximity to the site, potentially exposing individuals of that run to the adverse effects of pile-driving-induced acoustics. Juvenile fall-run sized Chinook salmon occur near the HOR gate construction site in December through July (DJFMP), with the majority (greater than 99 percent) in April through June. Mossdale trawl information taken by the DJFMP also indicates that winter-run and spring-run sized fish are found in small numbers near the HOR gate between December and June, particularly in March and April. This information, however, is derived using length-at-date criteria, which has been shown to have a false-positive rate approaching 1.0 mid-March to mid-April, when a few Chinook assigned to a winter-run race based on length-at-date are genetic winter-run (Harvey et al. 2014).

Adult fall-run Chinook salmon will migrate through the action area July through December. Most adult fall-run Chinook return to spawn in the rivers and tributaries of the Sacramento River basin, migrating through the channels of the Delta far from the HOR gate. Those fish migrating to the Stanislaus River, in the San Joaquin River basin, however, will pass the HOR gate construction site and be subject to pile-driving-induced acoustic effects.

Limiting pile driving at the HOR gate to the August 1 through October 31 work window is expected to minimize exposure to Chinook salmon species because:

- Winter-run Chinook salmon are not expected to be present near the HOR gate because it is far from their migration routes. Furthermore, the winter-run sized fish that have been found in the area of the HOR gate have been found there in March and April.
- The primary populations of spring-run Chinook salmon are located in the Sacramento River basin. A small proportion of juvenile spring-running fish may be present near the HOR gate in April and May. Yearling smolt spring-run Chinook salmon may also be present in the vicinity of the HOR gate in October, though likely in very low numbers.
- Late fall-run Chinook salmon are not expected to be present in the vicinity of the HOR gate because this area is far from any migration routes used by this run.

- Fall-run Chinook salmon are expected to be present in the vicinity of the HOR gate from April through June. And while adult fall-run will be migrating through the action area July through December, only a small proportion of the Central Valley population is expected to pass near the HOR gate.
- Given the timing of in-water construction activities, NMFS expects that the effects of pile-driving-induced acoustics at the HOR gate will not adversely affect winter-run, spring-run, or late fall-run Chinook salmon. NMFS expects that juvenile fall-run Chinook salmon will not be adversely affected, but a small proportion of immigrating adult fall-run in the Stanislaus River will be adversely affected by pile-driving-induced acoustic effects at the HOR gate construction site.

2.5.1.1.1.1.3.2 Steelhead Exposure and Risk

Juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Based on regional monitoring and CVP/SWP salvage data, less than one to two percent of the annual juvenile emigration from either basin is expected to occur during the proposed work window. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location, but their numbers appear to be considerably lower than those fish originating in the Sacramento River basin. It is not expected that that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate. Because pile driving associated with construction of the HOR gate occurs from August 1 through October 31, only a minimal amount of temporal overlap with the presence of juvenile CCV steelhead is expected.

Adult CCV steelhead from the Sacramento River basin are present in the Delta from June through November. Peak migration (approximately 69 percent of annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. Because pile driving at HOR gate occurs during August through October, only those adult steelhead migrating into the San Joaquin River basin during these months will be affected. It is anticipated that only a small proportion of the annual adult upriver migration will overlap with pile driving at HOR gate.

All adult and juvenile CCV steelhead from the San Joaquin River basin must pass through the lower San Joaquin River adjacent to the location of the HOR gate on their way to the ocean during the construction period. A proportion of downstream migrating fish in the mainstem are expected to enter Old River and migrate past the location of the HOR gate.

Pile-driving activities may potentially affect CCV steelhead at the HOR gate, but to differing degrees. Steelhead from the Sacramento River basin are not expected to be present at HOR gate. Adult steelhead from the San Joaquin River are present from September and October with peak upstream migration from November through January, after the end of the in-water work window. Minimal exposure of juveniles from the San Joaquin River basin is expected during this time frame (less than one percent of annual juvenile steelhead salvage occurs during the August through October time frame). Based on the spatial location of the proposed HOR gate and construction timing, NMFS expects that the acoustics effects of pile driving at HOR gate will adversely affect a small proportion of juvenile and some adult San Joaquin River basin steelhead.

2.5.1.1.1.1.3.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.4.3 Environmental Baseline*. Juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta during every month of the year, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta. Because of the widespread and year-round presence of juveniles and sub-adult life stages in the waters of the Delta, NMFS expects these life stages to be present in the south Delta, including the vicinity of the HOR gate, during construction periods. Juveniles and sub-adults could therefore become exposed to the pile-driving-induced acoustic effects associated with construction of the Head of Old River gate during the August 1 through October 31 in-water construction period. Exposure is expected to be limited due to the low density of green sturgeon in the waters of the south Delta and the San Joaquin River compared to the waters of the north Delta and the Sacramento River in general. NMFS therefore expects that the acoustics effects of pile driving at the HOR gate will adversely affect a small proportion of juvenile and sub-adult green sturgeon.

2.5.1.1.1.1.4 Barge Landing Locations

According to the proposed action description in the BA, contractors are expected to use barges to transport tunnel boring machine (TBM) components and other heavy or bulky equipment or materials to and from TBM launch sites. Barge landings are expected to be constructed to accommodate this activity. A total of seven barge landings are currently proposed (*Appendix 3.A Map Book for the Proposed Action*) at the following locations:

- Snodgrass Slough north of Twin Cities Road (adjacent to proposed intermediate forebay)
- Little Potato Slough (Bouldin Island south)
- San Joaquin River (Venice Island south)
- San Joaquin River (Mandeville Island east at junction with Middle River)
- Middle River (Bacon Island north)
- Old River (Victoria Island northwest)
- Old River (junction with West Canal at Clifton Court Forebay)

Construction of barge landings will include in-water pile driving as one of several activities that are likely to generate underwater noise. The BA proposes using barge landing docks supported by steel piles, though floating barges will be used where possible to minimize in-water construction activities. Docks would each occupy an overwater area of approximately 300 by 50 feet (0.34 acre) spanning five to nine percent of the total channel widths at the proposed locations. It is estimated that each barge landing would require vibratory and/or impact driving of 107 steel pipe piles (24-inch diameter) to construct the dock and connecting bridge. Based on the concurrent operation of four impact pile drivers at each site and an estimated installation rate of 60 piles per day, pile driving noise would be expected to occur over two days at each barge landing.

The timing of pile-driving activities at each barge landing location are shown in Table 3-14 trough Table 3-19.

Table 3-14. Timing for Construction Activities at Snodgrass Slough Landing

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2018	10/31/2018
Install support structure for decking	88 days	11/1/2018	3/4/2019
Cast Barge Deck	66 days	3/5/2019	6/4/2019
Finish Barge Landing	44 days	6/5/2019	8/5/2019

Table 3-15. Timing for Construction Activities at Little Potato Slough

Task Name	**Duration (days)**	**Start Date**	**End Date**
Install piles (in water work window)	66 days	8/1/2018	10/31/2018
Install support structure for decking	88 days	11/1/2018	3/4/2019
Cast Barge Deck	66 days	3/5/2019	6/4/2019
Finish Barge Landing	44 days	6/5/2019	8/5/2019

Table 3-16. Timing for Construction Activities at San Joaquin River Landings

Task Name	**Duration (days)**	**Start Date**	**End Date**
Install piles (in water work window)	66 days	8/1/2019	10/31/2019
Install support structure for decking	88 days	11/1/2019	3/4/2020
Cast Barge Deck	66 days	3/5/2020	6/4/2020
Finish Barge Landing	44 days	6/5/2020	8/5/2020

Table 3-17. Timing for Construction Activities on Middle River

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2019	10/31/2019
Install support structure for decking	88 days	11/1/2019	3/4/2020
Cast Barge Deck	66 days	3/5/2020	6/4/2020
Finish Barge Landing	44 days	6/5/2020	8/5/2020

Table 3-18. Timing for Construction Activities on Old River at Victoria Island

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2019	10/31/2019
Install support structure for decking	88 days	11/1/2019	3/4/2020
Cast Barge Deck	66 days	3/5/2020	6/4/2020
Finish Barge Landing	44 days	6/5/2020	8/5/2020

Table 3-19. Timing for Construction Activities on Old River at CCF

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2018	10/31/2018
Install support structure for decking	88 days	11/1/2018	3/4/2019
Cast Barge Deck	66 days	3/5/2019	6/4/2019
Finish Barge Landing	44 days	6/5/2019	8/5/20190

Table 3-20 (excerpted from Table 3.E-1 and 3.E-2 of the BA) describes the physical locations and details of the pile-driving actions described for the barge landings.

Table 3-20. Pile Driving Activity Details for Barge Landing Construction

Barge Landings										
Facility/ Structure	**Location**	**Lat/long**	**On land (distance to water in feet) or in water**	**River depth (ft)[1]**	**River width (ft)**	**Width of in-river construction (ft)**	**Length of construction along river bank (ft)**	**Proportion of river available for passage (percent)**	**Straight line distance to river bend (furthest upstream/ downstream location) (ft)**	**Distance to concurrent pile driving sites (ft)[2]**
Dock piles	Intake 2	38.40541, -121.51452	In water	-14	700	50	300	95	6,500-12,00	300
Dock piles	IF barge	38.28106, -121.49816	In water	-11	265	50	300	81	1,400-2,700	300
Dock piles	Bouldin Is. barge landing	38.08762, -121.54505	In water	-11 to -18	980	50	300	95	1,800-2,900	300
Dock piles	Venice Is. barge landing	38.06630, -121.54130	In water	-19 to -36	1,030	50	300	95	2,000-4,700	300
Dock piles	Mandeville Is. barge landing	38.04264, -121.53177	In water	-5 to -47	760	50	300	93	6,500-8,500	300
Dock piles	Bacon Is. barge landing	38.00392, -121.54343	In water	-8 to -28	340	50	300	85	1,200-1,800	300
Dock piles	Victoria Is. barge landing	37.91087, -121.56185	In water	-7	433	50	300	88	2,200-3,200	300
Dock piles	CCPP barge landing	37.85505, -121.56435	In water	-4 to -10	285	50	300	82	705-720	300

Table 3-21. Physical Data for Pilings at Barge Landing Locations

Barge Landings—Physical Data for Pilings								
Structure	Pile Type/Sizes	Total Piles per site	# of concurrent pile drivers per site	Piles per day	Strikes per pile (impact driving only)	Total strikes per day	Sound Attenuation Devices	Expected acoustic dampening in dB
Dock piles	24-inch steel piles	107	4	60	3151	18,900	None	NA

Table 3-22 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the barge landings based on application of the NMFS spreadsheet model and the assumptions presented in *Appendix 3.E Pile Driving Assumptions for the Proposed Action* (excerpted from Table 3.E-1 and 3.E.2.). During installation of the dock piles, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 3-22. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the Barge Landing Sites

Facility	Distance to 206 dB SPL Injury Threshold (feet)	Channel width	Percent of Channel Width (206)	Distance to Cumulative 187 dB SEL Injury Threshold 1, 2 (feet)	Percent of Channel Width (187)	Cumulative Distance (187)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Number of Construction Seasons (Year 1 or 2)	Timing of Pile Driving	Duration of Pile Driving (days)
Barge Landings Locations										
Intake 2 Location	46	700	7	1,774	100	3848	9,607	1	Aug–Oct	2
Snodgrass Slough	46	265	17.3	1,774	100	3848	9,607	1	Aug–Oct	2
Potato Slough	46	980	5	1,774	100	3848	9,607	1	Aug–Oct	2
San Joaquin (Venice Island)	46	1030	4.5	1,774	100	3848	9,607	1	Aug–Oct	2
San Joaquin River (Mandeville)	46	760	6	1,774	100	3848	9,607	1	Aug–Oct	2
Middle River (Bacon)	46	340	13.5	1,774	100	3848	9,607	1	Aug–Oct	2
Old River (Victoria Island)	46	433	10.6	1,774	100	3848	9,607	1	Aug–Oct	2
Old River (CCF)	46	285	16	1,774	100	3848	9,607	1	Aug–Oct	2

[1] Computed distances to injury thresholds are governed by the distance to "effective quiet" (150 dB SEL). Calculation assumes that single strike SELs <150 dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance.

[2] Distance to injury and behavioral thresholds assume an attenuation rate of 4.5 dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

The proposed action proposes to minimize the potential exposure of listed fish species to pile-driving noise by conducting all pile driving at barge landing locations between August 1 and October 31 when most species are least likely to occur in the action area. DWR will follow standard and provided AMMs, including the development and implementation of an underwater sound control and abatement plan outlining specific measures that will be implemented to avoid and minimize the effects of underwater construction noise on listed fish species (*Appendix 3.F*

General Avoidance and Minimization Measures, AMM9 Underwater Sound Control and Abatement Plan).

2.5.1.1.1.1.4.1 Chinook Salmon Exposure and Risk

Because barge landing locations are spread over a broad area of the Delta, activities at the landings may occur in areas where Chinook salmon are present. General run-timing in the Delta has been identified in section ***Error! Reference source not found. Error! Reference source not found.***.

Although Chinook salmon are likely to be present during this activity at some level, limiting pile driving at the barge landing locations to the August 1 through October 31 in-water work window is expected to minimize exposure to some runs and life stages of Chinook salmonid. The following summarize timing:

- Juvenile winter-run Chinook salmon are generally expected to be present in the Delta from November to April, but with small numbers possible in September and October; while adult winter-run are present in the Delta between November and June. Winter-run Chinook salmon exposure is also minimized compared to other runs because six of the seven landings are located on or near the San Joaquin River, which is not the main migratory corridor for winter-run Chinook salmon.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May, with adult spring-run presence between January and June.
- Adult late fall-run Chinook salmon are expected to be present in the Delta from October through March, peaking in December and January. However, juvenile late fall-run Chinook salmon may be present between July and January.
- Adult fall-run Chinook salmon may be present July through December, peaking in October. Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August.

Given the timing and location of in-water construction activities, NMFS expects that the effects of pile-driving-induced acoustic disturbances at the barge landing locations will not adversely affect juvenile or adult spring-run Chinook salmon. The in-water work window will reduce the exposure of juvenile and adult winter-run, juvenile fall-run and adult late fall-run Chinook salmon to pile-driving-induced acoustic effects. NMFS expects adverse effects to a small proportion of adult and juvenile late fall-run Chinook salmon to occur, as reduced exposure is expected, similar to winter-run Chinook salmon, as they are generally not found in the San Joaquin River basin. NMFS also expects adverse effects will occur to a small proportion of juvenile fall-run, and a large proportion of adult fall-run Chinook salmon.

2.5.1.1.1.1.4.2 Steelhead Exposure and Risk

As previously described in section ***Error! Reference source not found. Error! Reference source not found.***, *Appendix XX Section 1.3.3*, and section *2.5.1.1.1.1.1 North Delta Intake Locations*, CCV steelhead originating from the Sacramento and San Joaquin River basins can be present throughout the Delta. Accordingly, steelhead can potentially access one if not several of the barge landing locations in either the north (e.g., Snodgrass Slough) or south (e.g., CCF) Delta. The Sacramento River is the primary migration route for both juvenile and adult CCV steelhead from the Sacramento River basin and the only viable route during summer and early fall months because of the lack of sufficient flow to provide access to the Yolo Bypass. Because the Delta Cross Channel on the Sacramento River will be open during the in-water construction window, Sacramento River basin fish as well as the Mokelumne River basin fish are expected to have access to the Snodgrass Slough location. Waterways that access other landing locations, such as those on Little Potato Slough, the San Joaquin River, Middle River, and Old River, may be accessed by Sacramento River fish via the DCC as well as by San Joaquin basin fish outmigrating from the east side tributaries (e.g., Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries.

At nearly all barge landing locations, less than one to two percent of the annual juvenile population is expected to be present during the proposed work window (August 1 through October 31) because the majority of juvenile steelhead presence in the Delta near the barge landing locations is from January through May.

Because adult steelhead start to enter the Delta region as early as June, however, with peak presence in September and October, the in-water work window could expose up to approximately 80 percent of the annual adult escapement to activities at the barge landing locations, though the extent of exposure for the populations of the two basins (i.e., Sacramento vs. San Joaquin) depends on location. For landing locations in the central and south Delta, Sacramento River basin fish may be exposed by moving through the San Joaquin River corridor en route to the Sacramento River. Locations on the mainstem San Joaquin River will expose a greater proportion of that basin's population because the San Joaquin River is one of the expected migratory routes for this population. Also, the fraction of Sacramento River origin fish exposed to central and south Delta tributary locations will vary with location due to the greater distance from the mainstem San Joaquin River.

Given the timing and location of in-water construction activities, NMFS expects that the effects of pile-driving-induced acoustics at the barge landing locations will adversely affect a small proportion of juvenile steelhead at the barge landing locations. Because of the large proportion of the adult steelhead population that is present throughout the Delta during the in-water work window and the wide distribution of the barge landing locations throughout the Delta, however, NMFS expects that pile-driving activities at barge landings will adversely affect a large proportion of the adult steelhead.

Intake 2 NDD Location

The location with the highest likelihood of exposure to CCV steelhead during construction of a barge landing is Intake 2 on the Sacramento River. Based on the description provided, four pile drivers will be operating concurrently at this location for two consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site.

The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 46 feet, or approximately 7 percent of the channel width of 700 feet. The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 1,774 feet. This completely encompasses the entire river channel width at the barge landing location and extends the zone of injury for one day's pile driving activity the same distance up and down river from the barge landing location.

The estimated cumulative distance along the length of the river channel that exceeds the 187-dB SEL threshold is 3,848 feet. The distance to the 150-dB RMS threshold for behavioral effects is nearly 10,000 feet. Therefore, discernable impacts (behavioral modification) of the pile driving of barge landing pilings will extend nearly two miles upstream and downstream of the barge landing site if the channel were a straight linear alignment. The actual geometry of the site indicates that behavioral effects will extend upstream to the Clarksburg Bend and downstream to the location of Intake 3, a distance of nearly four river miles before river channel bends block the acoustic path of pile-driving noise.

The expected duration of pile driving is two days for completely inserting 107 piles. This amounts to approximately 6.5 percent of the days in each month (August through October). The percentage of exposed Sacramento River basin adult population per month, assuming equal distribution over each month, is as shown in the table below.

Table 3-23. Percentage of Exposed Sacramento River Basin Adult Population Per Month

Month	Percentage Annual Passage	Percentage Exposed
August	12.1	0.78
September	44.5	2.97
October	24.6	1.59

Thus, depending on the month in which pile driving occurs, between 0.8 and 3 percent of the adult population of CCV steelhead will be exposed to pile driving during piling installation for barge landings at the Intake 2 site.

The exposure to emigrating juvenile steelhead is considerably smaller because less than one to two percent of the juvenile migration will occur over the September and October period (less than 0.2 percent of the population over a two-day period).

Intermediate Forebay (Snodgrass Slough) Location

This location is likely to have the least probability of exposure of CCV steelhead to acoustic energy generated by pile driving during construction of a barge landing.

The IF forebay barge landing location is approximately 2.8 miles upstream of the DCC on Snodgrass Slough and is located on a non-migratory dead-end channel. Although the channel is open to waters that may contain CCV steelhead (DCC and Mokelumne River system), it is unlikely that many fish would move up into the dead-end slough. This is particularly true for adults moving upriver to spawning grounds.

Based on the description provided, four pile drivers will be operating concurrently at this location for two consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site.

The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 46 feet, or 17.3 percent of the 265-foot-wide channel at this location. The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 1,774 feet.

This completely encompasses the entire river channel width at the Snodgrass Slough barge landing location and extends the zone of injury for one day's pile driving activity the same distance up and down river from the barge landing location.

The estimated cumulative distance along the length of the river channel that exceeds the 187-dB SEL threshold is 3,848 feet. The actual geometry of the Snodgrass Slough channel at this location will allow the 187-dB SEL threshold to extend halfway to the mid-channel island to the south where the channel bends and divides into multiple channels.

The distance to the 150-dB RMS threshold for behavioral effects is nearly 10,000 feet. Therefore, discernable impacts (behavioral modification) of the pile driving of the barge landing pilings will extend nearly two miles upstream and downstream of the barge landing site if the channel were a straight linear alignment. The actual geometry of the site indicates that behavioral effects will extend downstream to the first channel bifurcation and bend associated with a mid-channel island (approximately 3,800 feet away).

The expected duration of pile driving is two days to completely insert 107 piles. This amounts to approximately 6.5 percent of the days in each month (August through October). The percentage of exposed Sacramento River basin CCV steelhead adult population per month, assuming equal distribution over each month is shown in the table below.

Table 3-24. Percentage of Exposed Sacramento River Basin CCV Steelhead Adult Population Per Month

Month	Percentage Annual Passage	Percentage Exposed
August	12.1	0.78
September	44.5	2.97
October	24.6	1.59

Thus, depending on the month in which the pile driving occurs, between 0.8 and 3 percent of the adult population of CCV steelhead will be exposed to pile driving during installation of pilings for the barge landings at the Intermediate Forebay site.

The exposure to emigrating juvenile steelhead is considerably less because fewer than one to two percent of the juvenile migration will occur over the September and October period (less than 0.2 percent of the population over a two-day period).

Bouldin Island (Potato Slough) Location

This location has a high likelihood of exposure for adult CCV steelhead from both the Sacramento and San Joaquin River basins.

The Bouldin Island location is on Potato Slough, just off of the mainstem San Joaquin River and just upstream of the mouth of the Mokelumne River and Georgiana Slough junctions. The landing dock location is situated on the apex of a 90-degree bend in the Slough.

Based on the description provided, four pile drivers will be operating concurrently at this location for two consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site.

The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 46 feet, or approximately five percent of the channel width of 980 feet. The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 1,774 feet. This completely encompasses the entire river channel width at the barge landing location and extends the zone of injury for one day's pile driving activity the same distance up and down the slough from the barge landing location until the sound waves encounter several bends and mid-channel islands in the slough, which will attenuate the distance the sound will travel.

The estimated cumulative distance along the length of the slough channel that exceeds the 187-dB SEL threshold is 3,848 feet. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 10,000 feet.

Therefore, discernable impacts (behavioral modification) from the pile driving of the barge landing pilings will extend upstream and downstream of the barge landing site within the channel until the alignment of the slough is altered by mid-channel islands and bends in the channel approximately 4000 feet to the southwest and 3700 feet to the southeast.

The expected duration of the pile driving is two days for completely inserting 107 piles. This amounts to approximately 6.5 percent of the days in each month (August through October). The percentage of exposed Sacramento River basin CCV steelhead adult population per month, assuming equal distribution over each month, is as shown in the table below.

Table 3-25. Percentage of Exposed Sacramento River Basin CCV Steelhead Adult Population Per Month

Month	Percentage Annual Passage	Percentage Exposed
August	12.1	0.78
September	44.5	2.97
October	24.6	1.59

The percentage of adult San Joaquin River origin CCV steelhead present at this location is expected to be considerably lower during August through October because peak migration does not occur until November through January.

Thus, depending on the month in which the pile driving occurs, between 0.8 and 3 percent of the adult population of Sacramento River basin CCV steelhead will be exposed to pile driving during pilings installation for the barge landing at Bouldin Island, with a lower percentage of the San Joaquin River population exposed due to the expected later run timing.

The exposure to emigrating juvenile steelhead is considerably less because less than one to two percent of the juvenile migration will occur during September and October (less than 0.2 percent of the population over a two-day period).

2.5.1.1.1.1.4.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section 2.4 *Environmental Baseline*. As discussed in those sections, juvenile and sub-adult sDPS green sturgeon may be present during any month of the year throughout the waters of the Delta, whereas adult green sturgeon are less widespread, primarily occurring in the waters of the north Delta along the principal migratory pathway between the ocean and upstream spawning habitats in the Sacramento River from late winter and early spring months into the late summer and early fall months each year. As the locations for the proposed barge landings are spread widely across the Delta, the potential for exposure of juvenile, sub-adult, and adult sDPS green sturgeon to the pile-driving-induced acoustic effects associated with their construction is tempered only by the August 1 through October 31 in-water construction period established for that effort. NMFS therefore expects that the acoustics effects of pile driving at the barge landing locations will adversely affect some juvenile, sub-adult, and adult green sturgeon.

2.5.1.1.1.2 Barge Traffic

According to the proposed action description in the BA, contractors are expected to use barges to deliver tunnel boring machine (TBM) components to TBM launch sites. Barges may also be used to transport other heavy or bulky equipment or materials to or from those sites. Barge landings will therefore be constructed at each TBM launch shaft site for loading and unloading construction equipment, materials, fill, and tunnel spoils. A total of seven barge landings are currently proposed in the PA (BA *Appendix 3.A Map Book for the Proposed Action*) at the following locations:

- Adjacent to Proposed Intermediate Forebay (on Snodgrass Slough north of Twin Cities Road)
- South Bouldin Island (on Little Potato Slough)
- South Venice Island (on San Joaquin River)
- East Mandeville Island (on San Joaquin River at junction with Middle River)
- North Bacon Island (on Middle River)
- Northwest Victoria Island (on Old River)
- Clifton Court Forebay (Old River at junction with West Canal)

Section *3.2 Conveyance Facility Construction* of the BA states that additional barge landings may be constructed, at the selected contractors' discretion, at the location of NDD Intake 2, Intake 3, and Intake 5 construction sites, at the Staten Island TBM retrieval shaft, and at the Banks and Jones Connections construction sites in the south Delta.

Based on information provided by the applicant, the two main destinations are the barge landings at CCF and Bouldin Island.

Barge operations associated with these landings are described as follows:

- Barges will be commercial vessels propelled by tugboats. Barge sizes have not been finalized, but are expected to be approximately 200 to 250 feet long and 50 feet wide with a draft of 6 to 12 feet. Commercial barge operators on the Sacramento River are required to operate in compliance with navigational guidelines.

- Barges will be required to use existing landings where possible and maintain a minimum waterway width greater than 100 feet (assuming maximum barge width of 50 feet).
- Barge operations will occur only during the work week and will not occur on weekends.
- Barges and tugs will travel at 5 knots loaded and 8 knots empty through Delta waterways and San Francisco Bay estuary.
- Each landing will be in use during the entire construction period at each location (five to six years). All landings will be removed at the end of the PA construction period.
- Barges are expected to be used for delivery of TBM components and may also be used for transport of precast tunnel segment liner sections, reusable tunnel material (RTM), crushed rock and aggregate, etc.; pile-driving rigs and barge-mounted cranes; suction dredging equipment; post-construction underwater debris removal; and other activities.
- According to information provided in the PA, approximately 11,060 barge trips are projected to carry tunnel segment liners from ports in San Francisco, Antioch, and Stockton to two primary landings of CCF and Bouldin Island via the Sacramento and San Joaquin rivers and adjacent waterways. This averages to approximately four one-way trips per day for up to 5.5 years to each landing location. The assumed number of trips to CCF is 4,370 (one-way) and to Bouldin Island is 6,689 (one-way). This information is shown in Table 3-27.
- Because barges may also be used for transport of bulk materials to the other landings as described above, a total of 15,000 one-way barge trips are projected as a conservative assumption (i.e., a greater number of trips is not expected to occur) for transport of all materials required by the PA. Number of trips and anticipated extent of use for secondary locations are shown in Table 3-26.
- To protect aquatic habitat and listed fish species, the barge operations plan (AMM7) will require barges and towing vessels to comply with standard navigation and operating rules to avoid or minimize physical disturbances and water quality impacts in the navigable waterways of the Delta. Where avoidance is not possible, the plan will include provisions to minimize effects as described in *Appendix 3.F General Avoidance and Minimization Measures*, *Section 3.F.2.7.4 Environmental Training* and *Section 3.F*.2.7.5 *Dock Approach and Departure Protocol*.

Table 3-26. Barge route and operation assumptions provided by DWR for the three anticipated barge origin locations and two primary landing locations

Barge Origin	Barge Landing Location	Estimated One-Way Distance (miles)	Number of Trips for Route (Assume 1/3 of trips from each Origin)
San Francisco	Bouldin Island	75.0	2,230
Stockton	Bouldin Island	18.5	2,230
Kie-Con (Antioch)	Bouldin Island	14.2	2,230
San Francisco	Clifton Court	93.6	1,457
Stockton	Clifton Court	37.1	1,457
Kie-Con (Antioch)	Clifton Court	32.8	1,457

Table 3-27. Barge operation and use assumptions provided by DWR for the secondary landing locations

Barge Landing Location	Number of One-Way Trips to Landing	Assumptions for Use
Intermediate Forebay	435	This site is near major highway so most if not all segment, fill, material, and equipment deliveries will be trucked in. Dock would be of limited use. One trip every five days.
Venice Island	500	No road access. This site may be used for 6 months of geotechnical investigations and 12 months' construction of potential emergency access shaft and safe haven; 100 barge trips total for equipment deliveries; 400 to build emergency access and safe havens.
Mandeville Island	400	No road access. This site may be used for 12 months of geotechnical investigations and 18 months construction of potential emergency access shaft and safe haven; 300 trips to build emergency construction access and safe haven; 100 barge trips total for equipment deliveries.

Barge Landing Location	Number of One-Way Trips to Landing	Assumptions for Use
Bacon Island	2200	Road access is available. Unloading facility will be used for 12 months for geotech investigations, 12 months to build retrieval pad, 24 months to build retrieval shaft and safe havens; 1400 barge trips for construction of retrieval pad; 200 trips for equipment deliveries and TMB removal; 600 trips for emergency construction access and safe haven.
Victoria Island	400	Road access is available. Unloading facility will be used for 12 months for geotech investigations, 24 months to build retrieval shafts and safe havens; 300 trips for construction of emergency access and safe havens; 100 barge trips total for equipment deliveries.

NMFS used the above information provided by the applicant to develop assumptions related to barge traffic in determining effects to listed species.

Because water depth in the Old River corridor to CCF is limited to 10 feet (i.e., the controlling depth at mean lower low water (MLLW)), vessels should not have a deeper draft than 10 feet (with a clearance of 2 feet from the bottom). The assumed length of tug boats is 65 to 100 feet with a beam of approximately 35 feet and a draft of approximately 6 to 8 feet. NMFS assumes that propeller disc diameter is approximately 70 percent of the draft, thus propeller discs will be approximately 50 to 70 inches in diameter, which corresponds to the dimensions for typical tugs operating in the Delta and San Francisco Bay. Tugs in the San Francisco Bay and Delta typically use shrouded propellers (e.g., Kort nozzles) that direct the thrust of the propeller jet in a confined cone providing more maneuverability, but potentially a more confined and longer lasting jet of propeller wash.

Based on an assumed velocity of 5 to 8 knots, a barge trip from the San Francisco port to the furthest landing location at CCF and back (187 miles round trip) can take upwards of 24 hours. NMFS therefore assumes that there is potential for barge operations to occur throughout a 24-hour period each day of the work week.

Based on the information provided by the applicant in Table 2-25, NMFS assumes that approximately 11,060 one-way trips will originate from one of the three origin locations and terminate at one of the two main barge landing locations at Bouldin Island or CCF throughout the construction phase of the PA. The assumed number of one-way trips to CCF is 4,370 and to Bouldin Island is 6,689. It is assumed that there will be four trips to each of these barge landings per day and four returning trips back to the port of origin for a total of 16 trips per day combined for both sites. Based on the estimated barge traffic information provided by the applicant, this results in 1,672 days of barge travel to Bouldin Island and 1,093 days of barge travel to CCFB.

During the five to six years of constructing the tunneled conveyance and other facilities, it is projected that up to 15,000 barge trips may be added to the daily vessel traffic in the action area. This is estimated based on an anticipated additional 4,000 one-way trips to the secondary locations show in Table 3-27. These trips will be spread over the time of constructing the tunneled conveyance and other facilities. Assuming that the 4,000 one-way trips and the required return trips (for a total of 8,000 one-way trips) are distributed over the five landing locations throughout a five-year period, the increase in traffic to these landings results in approximately one trip per day per landing or five one-way trips per day.

The applicant has indicated that the origins of barge traffic will either be from San Francisco, Antioch, or the Port of Stockton.

Vessels originating from San Francisco will have to transit the middle and north San Francisco Bay regions, San Pablo Bay, the Carquinez Strait, Suisun Bay, and then either follow the Sacramento or Stockton deep water ship channels (DWSC) to their terminal barge landing locations. Sites located adjacent to the NDD locations will have to follow the Sacramento River channel upstream of Rio Vista. Barge landing sites located at Snodgrass Slough, Venice Island, or Bouldin Island will require barges and tugs to move through the Stockton DWSC from Antioch to approximately Webb Point on the San Joaquin River (River Mile (RM) 22). Barges destined for Snodgrass Slough will have to navigate upriver through the Mokelumne River system (likely the North Fork of the Mokelumne River). Barges destined for Bouldin Island will enter Potato Slough from the San Joaquin River at RM 22. Barges destined for the Venice Island location will continue up the Stockton DWSC to Prisoners Point (RM 25) and then move into the Venice Reach. Barge traffic destined for either Mandeville Island or Bacon Island will move upriver in the Stockton DWSC to Middle River, then move southwards in Middle River to the barge landing locations. Barge traffic destined for either Victoria Island or the CCF locations will move through the Stockton DWSC to Old River, and then move southwards in Old River to those barge landing locations.

Vessels originating from the Port of Antioch will transit either the Sacramento DWSC or the Stockton DWSC. Routes are essentially the same as those barges originating from San Francisco, except that barge traffic destined for NDD locations may either go upstream in the Stockton DWSC and access the Sacramento DWSC via Threemile Slough (RM 15) or go back downstream and enter the Sacramento DWSC via Broad Slough.

Vessels originating from the Port of Stockton will use the Stockton DWSC to access the different barge landing sites at the previously mentioned navigation points.

2.5.1.1.1.2.1 Acoustic Effects of Barge and Tugboat Traffic

Barge and tugboat traffic will create additional sources of anthropogenic noise in the aquatic environment. This will be an acoustic-related stressor that can result in negative impacts to exposed aquatic organisms. Ships under power produce a substantial amount of mechanical- and flow-induced noise from power plant, propeller, and hull turbulence. Measurements of sound intensity from commercial shipping have shown sound levels up to approximately 180-dB (ref. 1 μPa) at the point source (1 meter from ship) (Kipple and Gabriele 2007). This level of noise will drop off by 40-dB at 100 yards away and approximately 53-dB lower at one quarter mile (Kipple and Gabriele 2007). The narrow confines of channels in the Delta region would indicate that the elevated noise levels generated by the passage of commercial vessels such as tugboats would extend essentially from bank to bank in the San Joaquin or Sacramento rivers, thus subjecting all fish within the confines of the channel to anthropogenic-produced noise conditions. The relatively rapid passage of the barge and tugboat past a given point will somewhat attenuate these effects by decreasing the duration of the elevated sound levels, but some temporary effects can be anticipated to occur, depending on the proximity of the exposed fish to the sound source.

The presence of underwater anthropogenic noise, such as that originating with shipping, may adversely affect a fish's ability to detect predators, locate prey, or sense their surrounding acoustic environment (Slabbekoorn et al. 2010, Radford et al. 2014). Other species of fish have been shown to respond to recorded ambient shipping noise by either reacting more slowly to predators, thus increasing their susceptibility to predation (Simpson et al. 2015, Simpson et al. 2016), or becoming hyper-alert and reacting more quickly to a visual predator stimulus, causing them to cease feeding and hide (Voellmy et al. 2014b). Voellmy et al. (2014a) states that elevated sound levels could affect foraging behavior in three main ways:

- noise could act as a stressor, decreasing feeding behavior directly through reduced appetite or indirectly through a reduction in activity and locomotion and alterations to the cognitive processes involved in food detection, classification, and decision making;
- noise could act as a distracting stimulus, diverting an individual's limited amount of attention from their primary task to the noise stimuli that have been added to the environment;
- noise could mask crucial acoustic cues such as those made by both prey and predators.

Fish also may exhibit noise-induced avoidance behavior that causes them to move into less suitable habitat for foraging or to feed when the noise has abated. Voellmy et al. (2014a) surmised that sustained decreases in food consumption could have long-term energetic impacts that result in reductions in growth, survival, and breeding success. Moreover, compensatory feeding activities could increase predation risks by increasing time exposed to predators or by forcing animals to feed in less favorable conditions, such as in times or areas of higher predation pressure.

In the proposed action, the increased noise produced by barge and tugboat traffic may result in salmonids fleeing the area of those noises and moving into the channel's shallowest margins. The channel margins of many Delta waterways have submerged and emergent vegetation (e.g. *Egeria*) and rock rip-rapped levees where predatory species are likely to occur in greater numbers than in the open waters of the channel. This scenario therefore could increase the predation risk of salmonids, particularly smolts. Likewise, elevated noise exposure can reduce the ability of fish to detect piscine predators either by reducing the sensitivity of the auditory response in the exposed fish or masking the noise of an approaching predator. Such would be the case if open water predators such as striped bass encounter the juvenile fish in the open channel while a barge and tug are present.

Within the context of the proposed action, the exposure to anthropogenically produced shipping noise will occur over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta) and over an extended period of time (5.5 to 6 years). Barge traffic will traverse nearly a hundred miles of waterways from San Francisco to the Port of Stockton and the sites of the NDD construction sites and CCF barge landing. Exposure to anthropogenically produced sounds will occur during each passage of a tugboat and barge and has been estimated to be approximately 30,000 cumulative individual trips over the course of the 5.5 to 6 years of construction (Table 3-27). The frequency of trips leading to either the CCF location in the south Delta or to Bouldin

Island on the main stem San Joaquin River will be approximately 8 times a day to each primary barge landing site (four round trips per day per primary barge landing site), with less frequent trips to the other barge landing sites. This is estimated to be at least 16 individual trips through the lower San Joaquin River reach between Antioch and Stockton each work day for the entire construction period of 5.5 to 6 years.

Noise associated with barge traffic may potentially affect multiple life stages of winter-run, spring-run, fall-run, and late fall-run Chinook salmon, steelhead, and green sturgeon. Both juveniles and adults of these species must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary while migrating to and from the ocean. A number of potential migration routes, such as Yolo Bypass, depend on the size and duration of available flows.

Barge activity from Chipps Island to the Golden Gate will, however, affect all migrating fish regardless of migration route. Effects related to the increased frequency and level of shipping noise related to the project are primarily expected to alter behavior in juvenile salmonids more so than adults because juveniles are more likely to be actively feeding and using the Delta and estuarine areas for rearing. Increased levels of shipping noise will influence their responses to foraging because elevated shipping noise can disrupt the effectiveness of foraging behavior by reducing the time spent actively feeding or increasing the effort required to successfully attack and consume prey items. The noise can affect predator avoidance by masking sounds of predator approach.

2.5.1.1.1.2.1.1 Winter-run Exposure and Risk

Detailed timing and spatial occurrence of winter-run Chinook salmon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*. Juvenile winter-run Chinook salmon are present in the Delta from October through April, with peak occurrence from December through March. Adult winter-run Chinook salmon enter the San Francisco Bay in November with their migration through the Delta and up the Sacramento River continuing until June. The bulk of the run passes RBDD between January and May, with the peak in mid-March. Relevant to barge traffic associated with the PA, adult winter-run Chinook salmon may be found in the Delta from November through June.

The increased level of anthropogenic shipping noise associated with the PA is expected to have an effect on winter-run Chinook salmon. Both adult and smolting juvenile winter-run Chinook salmon will be exposed considering that the upper reach of the Sacramento River below Keswick Dam is the single spawning location for winter-run Chinook salmon. Exposure for winter-run Chinook salmon is somewhat attenuated because most barge traffic is expected to use the Stockton DWSC and waterways associated with the lower San Joaquin River, rather than the Sacramento River, to reach the main landing locations at Bouldin Island and CCF. These locations are outside of the typical migratory corridors of winter-run Chinook salmon. Those winter-run that are exposed are most likely to be rearing, feeding juveniles. They are expected to have reduced fitness due to disruptions in their feeding behavior and may be at a higher risk to predation due to masking of acoustic signals from predators and disruption of predator avoidance behavior in exposed fish. Given these effects and the long-term, year-round traffic activity, NMFS therefore expects that the acoustics effects of barge traffic will adversely affect a small proportion of Sacramento River winter-run Chinook salmon.

2.5.1.1.1.2.1.2 Spring-run Exposure and Risk

The timing and spatial occurrence of spring-run Chinook salmon presence has been described in section *2.5.1.1.1 Acoustic Stress*.

Juvenile spring-run Chinook salmon may be present in the north Delta from November to June, with the majority (greater than 98 percent) of juveniles having outmigrated by the end of May. In some years, a few remaining fish may be migrating in early June, but the use of nearshore areas by juvenile salmon is generally reduced by June because most juveniles are large, actively migrating smolts that are known to move rapidly through the Delta and estuary during their seaward migration (Williams 2006). Adult spring-run Chinook salmon are present in the Delta from January to March as they begin to migrate upstream into the Sacramento River or San Joaquin River basin.

The increased level of anthropogenic shipping noise associated with the PA is expected to have an adverse effect on spring-run Chinook salmon. Some portion of both adult and juvenile spring-run Chinook salmon will be exposed to barge traffic for the approximately six years of activity. Although there are multiple barge landing locations in the north, central, and south Delta, most barge activity is expected to use the Stockton DWSC and waterways associated with the lower San Joaquin River, rather than the Sacramento River, to reach the main landing locations at Bouldin Island and CCF, which may decrease the likelihood of Sacramento basin origin spring-run Chinook exposure.

Although there is some uncertainty regarding the current number of spring-run Chinook salmon in the San Joaquin basin each year, there is indication they are present and will therefore be exposed to barge traffic in these areas. Additionally, projected routes from San Francisco Golden Gate to Chipps Island and back will expose migrations from both basins of juvenile and adult life stages of spring-run Chinook salmon. The juvenile life stage of spring-run Chinook salmon is the only life stage expected to be adversely affected by barge traffic exposure. Adverse effects are expected to be limited to reduced fitness due to disruptions in their feeding behavior and may be at a higher risk to predation due to masking of acoustic signals from predators and the disruption of predator avoidance behavior in exposed fish. Given these effects and the long-term, year-round traffic activity, NMFS expects that the acoustics effects of barge traffic will adversely affect a small proportion of spring-run Chinook salmon.

2.5.1.1.1.2.1.3 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of juvenile and adult CCV steelhead presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Adult CCV steelhead from the Sacramento River basin begin to migrate upriver from the Delta in June, with increasing numbers of fish arriving from August through September before tapering off in October and November. Peak migration (approximately 69 percent of the annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January.

The increased level of anthropogenic shipping noise is expected to have an effect on CCV steelhead. Both adult and smolting juvenile steelhead from the Central Valley will be exposed considering the wide spatial and temporal overlap of the stressor with steelhead migrations. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of CCV steelhead overlap with projected routes of the barge traffic from San Francisco.

Therefore all juvenile and adult steelhead from the Central Valley will have some level of exposure to the noise generated by barge traffic during their movements through the Delta and San Francisco Estuary regions.

A higher level of exposure is anticipated for steelhead originating in the San Joaquin River basin because most barge traffic will use the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF. Exposed steelhead are expected to have reduced fitness due to disruptions in their feeding behavior and may be at a higher risk of predation due to masking of acoustic signals from predators and disruption of predator avoidance behavior in exposed fish.

Given these effects and the high certainty of long-term, year-round traffic activity, coinciding with steelhead migration periods, NMFS expects that the acoustics effects of barge traffic will adversely affect a small proportion of CCV steelhead throughout the Delta.

2.5.1.1.1.2.1.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk.*

Duration of juvenile rearing in the estuary before ocean entry and transition to the sub-adult life stage is currently unknown. Juveniles captured in the Delta by Radtke (1966) ranged in size from 200 to 580 millimeters, suggesting that juveniles remain upriver for at least several months before entering the Delta. Recent studies of juvenile movement patterns in the Delta suggest that some individuals in the sDPS may enter the ocean and transition to the sub-adult life stage during their first year (Thomas and Klimley 2015), although the typical length of fish encountered in the ocean (greater than 600 millimeters) suggests that ocean entry typically occurs much later, probably at age 2 or 3. Length distributions of green sturgeon captured in the ocean may be biased high, however, because most of those records represent the incidental bycatch reported by commercial fisheries targeting relatively large fish species.

Adult sDPS green sturgeon enter San Francisco Bay between late January and early May, transiting the Delta and entering the Sacramento River from late winter through early summer to migrate to upstream spawning habitats. Post-spawn outmigration through the Delta typically occurs the following fall, although early outmigration has been observed in late spring and summer and may be related to elevated flows (Benson et al. 2007; Heublein et al. 2009).

When not in rivers for spawning, adults and sub-adults may enter the estuaries and bays along their coastal migration routes during early spring to summer months, presumably for feeding or seeking thermal refugia from cold upwells in the ocean during the summer months, returning to the ocean during the late summer and fall (Moser and Lindley 2007; Dumbauld et al. 2008; Lindley et al. 2011).

The lack of angler records of sub-adult-sized fish (roughly 60–100 centimeters) upstream of the Delta suggest sub-adults do not use freshwater riverine habitats. Recent studies in Oregon and

Washington state estuaries, however, suggest that the majority of the sDPS sub-adult and adult population may occupy non-natal estuaries during summer months (NMFS 2015). Despite the uncertainty and variability associated with Delta residence time by life stage, spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year.

NMFS has determined that juvenile, adult, and sub-adult sDPS green sturgeon are expected to be exposed to an increased level of anthropogenic noise originating from the continuous operation of barges for the five- to six-year construction period because of the widespread and year-round presence of these life stages of sDPS green sturgeon in the waters of the Delta.

The increased level of anthropogenic shipping noise is expected to have an effect on juvenile, sub-adult, and adult sDPS green sturgeon. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by juvenile and sub-adult life stages of sDPS green sturgeon rearing in the Delta during every month of the year. Additionally, the annual spawning migrations of adult green sturgeon between the ocean and upstream spawning habitats overlap with projected routes of the barge traffic from the Golden Gate Bridge in San Francisco to Chipps Island.

Therefore all juvenile, sub-adult, and spawning adult sDPS green sturgeon will have some level of exposure to the noise generated by barge traffic during their movements through the Delta and San Francisco Estuary. A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta where most of the barge traffic, using the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF, is expected to occur. Those sDPS green sturgeon exposed to the increased anthropogenic noise associated with barge traffic throughout the action area are expected to have reduced fitness due to disruptions in their feeding behavior and spawning migrations. Given these effects and the high certainty of long-term, year-round traffic activity over the course of approximately six years, NMFS expects that the acoustics effects of barge traffic will adversely affect a small proportion of sDPS green sturgeon throughout the Delta.

2.5.1.1.1.2.1.5 Fall/Late fall-run Exposure and Risk

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*. Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run Chinook salmon enter the San Francisco Bay in June and immigrate through the north Delta between July and December (Vogel and Marine 1991),with a peak in October.

The increased level of noise caused by the PA’s year-round barge traffic is expected to act as a stressor on fall-run Chinook salmon. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of fall-run Chinook salmon from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of fall-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco. Because the barges will be operating year-round in locations that all Central Valley fall-run Chinook salmon adults and juveniles must pass through, the entirety of both the adult and juvenile life stages will be exposed to noise caused by the PA barge traffic for the five- to six-year construction period.

A higher level of exposure is anticipated for fall-run Chinook salmon originating in the San Joaquin River basin because most barge traffic will use the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF.

Exposed fall-run Chinook salmon juveniles are expected to have reduced fitness due to disruptions in their feeding behavior and may be at a higher risk of predation due to masking of acoustic signals from predators and disruption of predator avoidance behavior in exposed fish. Given these effects and the high certainty of long-term, year-round traffic activity, coinciding with fall-run Chinook salmon rearing and migration periods, NMFS expects that the barge traffic noise will adversely affect individual fall-run Chinook salmon juveniles in the San Francisco Bay-Delta.

Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon are present in the Delta from July through September. Adult late fall-run Chinook salmon enter the San Francisco Bay November and immigrate past the are present through January (Vogel and Marine 1991).

The exposure and risk for late fall-run Chinook salmon is the same as for fall-run Chinook salmon originating from the Sacramento River. That is, late fall-run Chinook salmon are likely to be exposed to PA barge traffic noise in the San Francisco Bay-Delta, resulting in adverse effects to juveniles.

2.5.1.1.2 Sediment Concentration and Turbidity Stress

The PA includes activities that are likely to increase suspended sediments and elevate turbidity above natural levels in the water column, which may affect listed fish. Re-suspension and deposition of instream sediments are an indirect effect of pre-construction, construction, and maintenance activities occurring in the river channel and on the river banks within the action area. Specific activities that will contribute to suspended sediments and elevated turbidity include pre-construction dredging; geotechnical borings; clearing and grubbing at construction sites; pile driving at intake sites, HOR, CCF, and at barge landings; and increased vessel traffic during construction.

Elevated turbidity and suspended sediment levels have the potential to adversely affect salmonids during all freshwater life stages by clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence (Phillips and Campbell 1961), burying eggs or alevins, scouring and filling in pools and riffles, reducing primary productivity and photosynthesis activity (Cordone and Kelley 1961), and affecting intergravel permeability and dissolved oxygen levels (Zimmerman and Lapointe 2005; Lisle and Eads 1991).

Fish behavioral and physiological responses indicative of stress include: gill flaring, coughing, avoidance, and increased blood sugar levels (Berg and Northcote 1985; Servizi and Martens 1992). Excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival (Waters 1995).

Increased turbidity and suspended sediment levels associated with proposed project construction activities will occur downstream of primary spawning, egg incubation, and fry emergence areas and therefore are not expected to impact redds or incubating eggs.

Given the activity locations, increased turbidity and suspended sediment levels may negatively impact fish populations temporarily when deposition of fine sediments fills interstitial substrate spaces in food-producing riffles, reducing the abundance and availability of aquatic insects and cover for juvenile salmonids (Bjornn and Reiser 1991).

Suspended solids and turbidity generally do not acutely affect aquatic organisms unless they reach extremely high levels (i.e., levels of suspended solids reaching 25 mg/L). At these high levels, suspended solids can adversely affect the physiology and behavior of aquatic organisms and may suppress photosynthetic activity at the base of food webs, affecting aquatic organisms either directly or indirectly (Alabaster and Lloyd 1980, Lloyd 1987, Waters 1995).

Another impact to fish from suspended sediment is exposure to contaminant-laden sediments released into the water column. As contaminants remaining in buried sediments are re-suspended, introduction of compounds into the overlying water column result in exposure risks to passing aquatic organisms, including listed salmonids and green sturgeon. This is discussed further in section *2.5.1.1.3 Contaminant Exposure*.

Increased sediment concentrations can also affect fish by reducing feeding efficiency or success and stimulating behavioral changes. Sigler et al. (1984) found that turbidities between 25 and 50 NTUs reduced growth of juvenile coho salmon and steelhead, and Bisson and Bilby (1982) reported that juvenile coho salmon avoid turbidities exceeding 70 NTUs. Turbidity likely affects Chinook salmon in much the same way it affects juvenile steelhead and coho salmon because of similar physiological and life history requirements between the species. Newcombe and Jensen (1996) also found increases in turbidity could lead to reduced feeding rate (sublethal effects) and behavioral changes such as alarm reactions, displacement or abandonment of cover, and avoidance, which can lead to increased predation and reduced feeding. At high suspended sediment concentrations for prolonged periods, lethal effects can occur.

The proposed action includes implementation of a SWPPP and BMPs to control erosion and storm water sediment runoff as necessary to minimize erosion and sediment-laden runoff from construction areas (BA Appendix 3F AMM4). Additionally, the Clean Water Act § 401Water Quality Certification that will be issued by the U.S. Army Corps of Engineers for the proposed action will limit the potential effects of fine sediment on fish by limiting the maximum increase of turbidity in the water column over background levels.

NMFS (2008) reviewed observations of turbidity plumes during installation of riprap for bank protection projects along the Sacramento River and concluded that visible plumes are expected to be limited to only a portion of the channel width, extend no more than 1,000 feet downstream, and dissipate within hours of cessation of in-water activities. Based on these observations, NMFS concluded that turbidity levels produced by such activities could disrupt normal feeding and sheltering behavior of salmonids (National Marine Fisheries Service 2008). Although turbidity increases during construction activities can typically result in short-term and localized impacts, some of the proposed activities are expected to last for the majority of daylight hours through all months of the year and will therefore more likely result in longer-term impacts. Once cofferdams have been constructed, isolating the work area, the potential for the proposed project activities to cause significant increases in downstream turbidity levels is low.

2.5.1.1.2.1 Pile Driving

2.5.1.1.2.1.1 North Delta Diversion Intake Locations

Pile-driving activities at the north Delta diversion intake locations are described in section *2.5.1.1.1.1.1 North Delta Intake Locations*.

2.5.1.1.2.1.1.1 Species Exposure and Risk

Pile driving at the NDD intake locations is expected to cause minimal turbidity-related impacts to juvenile salmonids because few juveniles will be present within the work window. For construction of the NDD, small numbers of juvenile winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead are expected to occur at the locations during the margins of the June 1 through October 31 in-water work window, which may cause those individuals to be exposed to increased turbidity caused by pile driving. In October about two percent of juvenile winter-run sized Chinook salmon are expected to be found in the vicinity of the NDD, while in June less than two percent of spring-run sized Chinook salmon and about one to two percent of juvenile steelhead could be migrating past the NDD intake location. Less than one percent of the annual juvenile fall-run Chinook salmon population would be found near the NDD site in June through October.

Adult winter-run Chinook salmon and adult spring-run Chinook salmon would not be expected to be found in the vicinity of the NDD during the in-water work window. Adult steelhead and green sturgeon may potentially be found within the Delta during any month of the year, and unlike winter- and spring-run Chinook salmon, steelhead and sturgeon can spawn more than once. Thus post-spawn adults may potentially move back downstream through the Delta after completing spawning in their natal streams. Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Adult fall-run Chinook salmon are expected to pass the NDD intake locations between July and December, with the peak of the migration in October. Timing of adult fall-run Chinook salmon, steelhead, and green sturgeon presence in the Delta has the potential to expose fish destined for the Sacramento River basin to the effects of pile-driving-induced turbidity.

Therefore NMFS expects that increased sediment concentrations from pile driving at the NDD intake location would affect a small proportion of juvenile steelhead and winter-, spring-, and fall-run Chinook salmon and a small proportion of adult winter- and spring-run Chinook salmon and sturgeon. NMFS expects that the effect will adversely affect some steelhead and fall-run Chinook salmon adults and some juvenile green sturgeon.

2.5.1.1.2.1.2 Clifton Court Forebay

Pile-driving activities at the Clifton Court Forebay are described in section *2.5.1.1.1.1.2 Clifton Court*, with in water-work window July 1 to November 30.

2.5.1.1.2.1.2.1 Species Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook into CCF during construction activities, there is the potential for adverse effects of pile driving at the Clifton Court Forebay including turbidity-related impacts to juvenile winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead, which may also disrupt the normal behavior or foraging success of exposed adult steelhead and green sturgeon. For CCF construction, the action agency has proposed a modified in-water work window of July 1 to November 30, which will limit the potential for exposure to pile-driving-induced turbidity. Winter- and spring-run Chinook salmon would not be present in the CCF during the in-water work window, while less than one percent of fall-run juvenile Chinook salmon would be expected to be present July through November.

Based on the timing of adult migrations, adult winter-run Chinook salmon, adult spring-run Chinook salmon, and adult fall-run Chinook salmon would not be expected to be found in the CCF during the in-water work window.

Adult steelhead may potentially be found within the Delta during any month of the year, and, typically, adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Steelhead entering the San Joaquin River basin are believed to have a later spawning run, where adults enter the system starting in late October through December, indicating presence in the Delta a few weeks earlier.

Timing of adult steelhead migration has the potential to expose fish destined for either the Sacramento River basin or the San Joaquin River basin to the turbidity-related impacts of pile driving. Green sturgeon are also thought to be present in the Delta at any time of the year, potentially exposing that species to pile-driving-induced turbidity. Turbidity impacts caused by pile driving operations are somewhat minimized by the relatively small area of effect relative to ambient turbidity.

NMFS expects that increased sediment concentrations from pile driving at CCF would not adversely affect juvenile steelhead, adult green sturgeon, and juvenile winter-run and spring-run Chinook salmon. Given the multiple years of pile driving activity and the documented presence at the CCF during the in-water work window, however, NMFS expects that increased sediment concentrations from pile driving at CCF will adversely affect a few juvenile fall-run Chinook salmon, adult winter-, spring-, and fall-run Chinook salmon, and juvenile sturgeon.

2.5.1.1.2.1.3 HOR Gate

Pile driving activities at the Head of Old River gate are described in section *2.5.1.1.1.1.3 HOR Gate*.

2.5.1.1.2.1.3.1 Species Exposure and Risk

Pile driving at the Head of Old River gate is not expected to cause turbidity-related impacts to juvenile winter-run Chinook salmon, juvenile spring-run Chinook salmon, fall-run Chinook salmon, or juvenile steelhead, but may disrupt the normal behavior of exposed green sturgeon and those adult fall-run Chinook salmon and CCV steelhead coming from or going to the San Joaquin River.

For the HOR gate construction, the action agency has proposed a reduced in-water work window of August 1 to October 31, which will limit the potential for exposure to pile-driving-induced turbidity. Based on the timing of migrations, winter-run Chinook salmon, spring-run Chinook salmon, and juvenile fall-run Chinook salmon and steelhead are not expected to be present during the in-water work window. Adult steelhead may potentially be found within the Delta during any month of the year, and, typically, adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Steelhead entering the San Joaquin River basin enter the system starting in late October through December. Timing of adult steelhead migration has the potential to expose fish destined for the San Joaquin River basin to the physical impacts of pile driving. Green sturgeon are also thought to be present in the Delta at any time of the year, which potentially exposes that species to pile-driving-induced turbidity at the HOR gate as well.

Turbidity impacts caused by pile-driving operations are somewhat minimized by the relatively small area of effect. NMFS expects that increased sediment concentrations from pile driving at the HOR gate would not adversely affect winter-run Chinook salmon, spring-run Chinook salmon, and juvenile fall-run Chinook salmon and steelhead. Given the multiple years of pile driving activity and the documented presence at the HOR gate during the in-water work window, however, NMFS expects that the increased sediment concentrations from pile driving will adversely affect some adult fall-run Chinook salmon, adult steelhead, and juvenile, sub-adult, and adult green sturgeon.

2.5.1.1.2.1.4 Barge Landing Locations

Pile driving activities at the barge landing locations are described in section *2.5.1.1.1.1.4 Barge Landing Locations*.

2.5.1.1.2.1.4.1 Species Exposure and Risk

Pile driving during construction of the barge landing locations is not expected to cause turbidity-related impacts to juvenile spring-run Chinook salmon, juvenile fall-run Chinook salmon, and juvenile steelhead, but may displace or disrupt the normal behavior of exposed winter-run Chinook salmon, adult steelhead, and green sturgeon.

There will be seven barge landing locations throughout the Delta. For their construction, the action agency has proposed a reduced in-water work window of August 1 to October 31, which will limit the potential for exposure to pile-driving-induced turbidity.

At the barge landing locations, juvenile spring-run Chinook salmon and juvenile steelhead are not expected to be present during the in-water work window because it falls outside their migration period. In October it is expected that about two percent of juvenile winter-run-sized Chinook salmon will have begun migrating through the Delta and may be present in the vicinity of the Snodgrass Slough barge landing location. Adult steelhead may potentially be found within the Delta during any month of the year. Typically, adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Steelhead entering the San Joaquin River basin enter the system starting in late October through December. Timing of the adult fall-run Chinook salmon and steelhead migrations has the potential to expose fish destined for either the Sacramento River basin or the San Joaquin River basin to the turbidity impacts of pile driving.

Green sturgeon are also thought to be present in the Delta at any time of the year, potentially exposing that species to pile-driving-induced turbidity at the barge landing locations as well.

Turbidity impacts caused by pile-driving operations are somewhat minimized by the relatively small area of effect. NMFS expects that increased sediment concentrations from pile driving at the barge landing locations would not adversely affect spring-run Chinook salmon, juvenile fall-run Chinook salmon, and juvenile steelhead. NMFS expects that increased sediment concentrations from pile driving will adversely affect some winter-run Chinook salmon, adult fall-run Chinook salmon, adult steelhead, and juvenile, sub-adult, and adult green sturgeon, however, because of their documented presence at the barge landing locations during the in-water work window.

2.5.1.1.2.2 Barge Traffic

Barge operations, routes, and assumptions are described in section *2.5.1.1.1.2 Barge Traffic*.

Sediment Concentration and Turbidity Effects of Barge and Tugboat Traffic

Large vessel operation can cause sediment disturbance, potentially increasing localized turbidity levels and exposing latent contaminants through sediment resuspension. The passage of a ship hull through the water creates a series of complex hydraulic actions that are affected by hull shape, vessel speed, channel geometry, and hull displacement. The forward movement of the hull displaces water both forward and laterally, producing waves that spread both at an angle and perpendicular to the sailing line (Seelig 2002). These wakes encounter the shallow edges of the channel and disturb bottom sediment forcing it into the water column as resuspended sediment (Mazumder et al. 1993, Parchure et al. 2001).

Passage of large ships can create a “drawdown” of water level along the bank, followed by the sharp jump in response. The effects of this are accentuated by increased ship speeds, shallow channel depths, shallow-water berms along the channel edge, and the vessel’s proximity to the sailing line. Therefore, the effect is magnified in confined channels such as the Old River corridor. NMFS will assume that the entire length of the tug and barge transit will have these conditions present, although the magnitude will vary with channel configuration.

Large and small vessels operated in confined channels with minimal under-keel clearance introduce additional disturbance opportunity as the propeller jet interacts with the bottom sediment (Mazumder et al. 1993, Beachler and Hill 2003). Studies have also indicated that propeller washes directed at confining structures like levee banks or dock structures or in tight quarters requiring extensive maneuvering accelerate erosion of the bottom substrate (Hamill *et al.* 1999). Large vessel traffic can resuspend and expose heavier grain sediments to fairly deep depths (greater than 23 meters) within maritime ports and navigation channels while maneuvering (Lepland et al. 2010).

Within the context of the proposed action, the disturbance of sediments will occur over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta) and over an extended period of time (5.5 to 6 years). Barge traffic will traverse nearly a 100 miles of waterways from San Francisco to the Port of Stockton and the sites of the NDD construction sites and CCF barge landing. While most of the route will be in open water with fairly deep dredged channels (shipping channels), the barge landing locations in the Delta will require maneuvering in confined, shallow waterways.

It is expected that the passage of barges and tugs coupled with the effects of propeller jet during normal operations and docking could resuspend thousands to hundreds of thousands of tons of sediment material each year. Resuspension of material will occur during each passage of a vessel and barge and has been estimated to be approximately 30,000 trips over the course of the 5.5 to 6 years of construction. The frequency of disturbance will be approximately eight times a day to each of the primary barge landing sites (four round trips per day per primary barge landing site), with less frequent trips to the other barge landing sites. During each trip, however, sediment that has been resuspended by the passage of one barge is likely to be resuspended again during the return trip of that same barge or by other barges bringing materials to that same landing. This essentially produces a constant influx of newly resuspended materials in the channels leading to the primary barge landing sites on a near daily basis.

The increased sediment concentration associated with barge traffic has potential to affect multiple life stages of winter-run, spring-run, fall-run, and late fall-run Chinook salmon, steelhead, and green sturgeon. Both juveniles and adults of these species must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary while migrating to and from the ocean. A number of potential migration routes, such as the Yolo Bypass, may be available depending on the size and duration of available flows. Barge activity from Chipps Island to the Golden Gate will affect all migrating fish regardless of migration route. Effects related to the increased frequency of shipping activity related to the project are primarily expected to alter behavior in juvenile salmonids more so than adults because juveniles are more likely to be actively feeding and using the Delta and estuarine areas for rearing. Those exposed will be subject to physical and behavioral responses identified in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. Such responses include gill clogging, abrading, or flaring; location avoidance; interstitial filling of riffle substrate; and reduced feeding success.

2.5.1.1.2.2.1.1 Winter-run Exposure and Risk

Detailed timing and spatial occurrence of winter-run Chinook salmon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Juvenile winter-run Chinook salmon are present in the Delta from October through April, with peak occurrence from December through March. Adult winter-run Chinook salmon may be found in the Delta from November through June. All adult and juvenile winter-run Chinook salmon must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary on their way to and from the ocean.

The potential for increased sediment concentration because of increased barge traffic will act as a stressor on winter-run Chinook salmon. Both adult and smolting juvenile winter-run Chinook salmon will be exposed considering that the upper reach of the Sacramento River below Keswick Dam is the single spawning location for winter-run Chinook salmon. Exposure for winter-run Chinook salmon is somewhat attenuated because most of the barge traffic is expected to use the Stockton DWSC and waterways associated with the lower San Joaquin River, rather than the Sacramento River, to reach the main landing locations at Bouldin Island and CCF. These locations are outside the typical migratory corridors of winter-run Chinook salmon. From Chipps Island to the Golden Gate, however, both migrations of juvenile and adult life stages of winter-run Chinook salmon overlap with projected routes of barge traffic from San Francisco.

Exposed fish will be subject to physical and behavioral responses identified in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. Because of reduced fitness and stress caused by the barge traffic-induced turbidity plumes in the migratory corridor and the long-term, year-round traffic activity, NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect some individual Sacramento River winter-run Chinook salmon.

2.5.1.1.2.2.1.2 Spring-run Exposure and Risk

The timing and spatial occurrence of spring-run Chinook salmon presence has been described in section *2.5.1.1.1 Acoustic Stress*.

Juvenile spring-run Chinook salmon may be present in the north Delta from November to June, with the majority (greater than 98 percent) of juveniles having outmigrated by the end of May. In some years, a few remaining fish may be migrating in early June, but the use of nearshore areas by juvenile salmon is generally reduced by June because most juveniles are large, actively migrating smolts that are known to move rapidly through the Delta and estuary during their seaward migration (Williams 2006). Adult spring-run Chinook salmon are present in the Delta from January to March as they begin to migrate upstream into the Sacramento River or San Joaquin River basin.

The potential for increased sediment concentration due to increased barge traffic will act as a stressor on spring-run Chinook salmon. Some portion of both adult and juvenile spring-run Chinook salmon will be exposed to barge traffic for the approximately six years of activity. Although there are multiple barge landing locations in the north, central, and south Delta, most barge activity is expected to use the Stockton DWSC and waterways associated with the lower San Joaquin River, rather than the Sacramento River, to reach the main landing locations at Bouldin Island and CCF. This may decrease the likelihood of Sacramento basin origin spring-run Chinook exposure. Although there is some uncertainty regarding the current number of spring-run Chinook salmon in the San Joaquin basin each year, monitoring shows that they are present and will therefore be exposed to barge traffic in these areas. Additionally, projected routes from the Golden Gate to Chipps Island and back will affect migrations from both basins of juvenile and adult life stages of spring-run Chinook salmon. Adverse effects are expected to be limited to reduced fitness because of stress related to turbidity plumes from barge traffic in the migratory corridors.

Exposed fish will be subject to physical and behavioral responses identified in *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. Adverse effects resulting in injury or death are not expected to occur. Because of reduced fitness and stress caused by the barge-traffic-induced turbidity plumes in the migratory corridor and the long-term, year-round traffic activity, NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect some individual spring-run Chinook salmon.

2.5.1.1.2.2.1.3 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of CCV steelhead presence has previously been described in section *2.5.1.1.1 Acoustic Stress*.

Juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Adult CCV steelhead from the Sacramento River basin begin to migrate upriver from the Delta in June, with increasing numbers of fish arriving from August through September, before tapering off in October and November. Peak migration (approximately 69 percent of the annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. All adult and juvenile CCV steelhead must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary on their way to and from the ocean.

The potential for increased sediment concentration due to increased barge traffic will act as a stressor on steelhead. Both adult and smolting juvenile steelhead from the Central Valley will be exposed considering the wide spatial and temporal overlap of the stressor with steelhead migrations. Multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of CCV steelhead overlap with projected routes of barge traffic from San Francisco. Therefore all juvenile and adult steelhead from the Central Valley will have some level of exposure to the noise generated by barge traffic during their movements through the Delta and San Francisco Estuary regions.

A higher level of exposure is anticipated for steelhead originating in the San Joaquin River basin because most barge traffic will use the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF. Those exposed will be subject to physical and behavioral responses identified in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. Exposed steelhead are expected to have reduced fitness because of stress related to turbidity plumes from the pulsed sediment plumes in the migratory corridors. Given these effects and the high certainty of long-term, year-round traffic activity, coinciding with steelhead migration periods, NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect some individual CCV steelhead throughout the Delta.

2.5.1.1.2.2.1.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*. Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year.

NMFS has determined that juvenile, adult, and sub-adult sDPS green sturgeon are expected to be exposed to elevated concentrations of suspended sediment and increased frequency of turbidity plumes originating from the continuous operation of barges throughout the action area during the five- to six-year construction period owing to their widespread and year-round presence in the waters of the Delta.

The potential for increased suspended sediment concentrations and frequency of turbidity plumes in the Delta due to increased barge traffic is expected to have an effect on juvenile, sub-adult, and adult sDPS green sturgeon. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by juvenile and sub-adult life stages of sDPS green sturgeon rearing in the Delta during every month of the year. Additionally, the annual spawning migrations of adult green sturgeon between the ocean and upstream spawning habitats overlap with the projected routes of barge traffic anticipated between the Golden Gate and Chipps Island. Therefore all juvenile, sub-adult, and spawning adult sDPS green sturgeon will have some level of exposure to the periodic increases of turbidity plumes and elevated concentrations of suspended sediment generated by barge traffic during their movements through the Delta and San Francisco Estuary.

A higher level of exposure is anticipated for juvenile and sub-adult life stages of green sturgeon compared to adults. Juveniles and sub-adults have an extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats.

The adverse effects to fish typically associated with elevated concentrations of suspended sediment in the water column has been generally described in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. It is unclear, however, to what extent those sDPS green sturgeon that are exposed to the increased concentrations of suspended sediment and frequency of turbidity plumes associated with increased barge traffic throughout the action area will be affected. It is possible that higher concentrations of suspended sediment and frequency of turbidity plumes in the Delta may interfere with normal sturgeon feeding and migratory behavior. As these fish are benthically oriented and have evolutionarily adapted to turbid flowing waters, however, adverse effects associated with this particular stressor may not be as deleterious to sturgeon feeding and movement through the Delta as they are to salmonids in general.

Given these effects and the high certainty of long-term, year-round barge traffic over the course of approximately six years, NMFS expects that the elevated suspended sediment concentrations and frequency of turbidity plumes in the waters of the Delta associated with increased barge traffic will adversely affect some individual sDPS green sturgeon throughout the Delta.

2.5.1.1.2.2.1.5 Fall/Late fall-run Exposure and Risk

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run Chinook salmon enter the San Francisco Bay in June and immigrate through the north Delta between July and December (Vogel and Marine 1991),with a peak in October.

The potential for increased sediment concentration due to increased barge traffic will act as a stressor on fall-run Chinook salmon. Multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of fall-run Chinook salmon from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of fall-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco. Because the barges will be operating year-round in locations that all Central Valley fall-run Chinook salmon adults and juveniles must pass through, the entirety of both adult and juvenile life stages will be exposed to increased sediment concentration caused by the PA barge traffic for the five- to six-year construction period.

A higher level of exposure is anticipated for fall-run Chinook salmon originating in the San Joaquin River basin because most barge traffic will use the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF.

Exposed fall-run Chinook salmon will be subject to physical and behavioral responses identified in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. Exposed fall-run Chinook salmon are expected to have reduced fitness because of stress related to turbidity plumes from the pulsed sediment plumes in the migratory corridors. Given these effects and the high certainty of long-term, year-round traffic activity coinciding with fall-run Chinook salmon rearing and migration periods, NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect individual fall-run Chinook salmon juveniles and adults in the San Francisco Bay-Delta.

Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon are present in the Delta from July through September. Adult late fall-run Chinook salmon enter the San Francisco Bay in November and are present through January (Vogel and Marine 1991).

Exposure and risk for late fall-run Chinook salmon is the same as for fall-run Chinook salmon originating from the Sacramento River. That is, late fall-run Chinook salmon are likely to be exposed to increased sediment concentration and turbidity effects caused by PA barge traffic in the San Francisco Bay-Delta, resulting in adverse effects to juveniles and adults.

2.5.1.1.2.3 Geotechnical Analysis

Geotechnical analysis will be required in order to adequately characterize ground conditions and evaluate site-specific soil characteristics to better define the strength, permeability, and compressibility of the supporting foundation soils surrounding the proposed tunnels and shafts along the alignment of the proposed conveyance facilities and their associated structures. A geologic model will then be developed that will appropriately identify and mitigate geologic risks and hazards associated with the construction and long-term operation of the PA. These analyses are expected to be completed at all locations that will be subject to pile driving, as identified in the PA. NMFS therefore assumes that geotechnical borings will be drilled at the NDD intake locations, CCF, the HOR gate locations, and all barge landing locations.

Activities associated with geotechnical analysis can cause bed disturbance, potentially resuspending bed materials and increasing suspended sediment concentrations and local turbidity levels. Approximately 90 to 100 overwater geotechnical borings and cone penetration tests (CPTs) are proposed to be drilled in the Delta waterways between 2015 and 2018. These include approximately 30 overwater geotechnical borings and CPTs in the Sacramento River to obtain geotechnical data for the proposed intake structures (between 6 and 10 borings and CPTs being conducted at each of the Intakes 2, 3 and 5) located on the Sacramento River between Courtland and the Clarksburg area. The depths of borings and CPTs are planned to range between 100 and 200 feet below the mud line (i.e., river bottom).

The PA indicates that overwater drilling will only occur during the time period from August 1 until October 31 between the hours of sunrise and sunset. This period is the recognized window of opportunity to avoid or minimize disturbance for sensitive environmental resources. Duration of drilling at each location will vary depending on the number and depth of the holes at each location, drill rate, and weather conditions, but are not expected to exceed 60 days at any one location.

The drilling will be conducted with a rotary drilling rig mounted on a shallow-draft barge or ship. Multiple barges or ships may be operated concurrently. The barge or ship will be anchored into the bottom of the channel with two to four spuds to prevent the vessel from drifting while the work is being performed. The spuds are steel pipes mechanically lowered into the channel bottom. The barge or ship will be mobilized from an established marina and will be anchored either at the drill sites or at Coast Guard established anchorage points. Personnel will access the barge or ship via a support boat from an established marina. When a drill rig remains on a boring location for more than one day, the drill apparatus and casing will remain in the water column and drill hole to minimize sediment disturbance of the river bottom.

The drill apparatus consists of a 6- to 8-inch-diameter conductor casing that extends from the barge deck, through the water column, and into the soft sediments of the river bottom. The small diameter of the casing would not impede water flow or the migration patterns of fish. All drilling rods, samplers, and other down-hole equipment pass through the inside of the casing, which effectively separates them from the water.

There are no loose items or netting on the casing that would entrap or snag fish. The borings will be advanced using mud rotary method and will be drilled and sampled to a maximum depth of approximately 200 feet below the bottom of the channel. In this case, the term “mud” refers to the use of bentonite clay added to the boring to allow removal of drill cuttings and to stabilize the boring. Initially, the boring will be advanced by pushing an approximate 6- to 8-inch-diameter conductor casing, which will extend from the top of the barge or drill ship deck, an approximate depth of 10 to 15 feet or more below the mud line of the river channel. The conductor casing will be used to confine the drill fluid and cuttings within the drill hole and operating deck of the barge or drill ship and prevent any inadvertent spillage into the water. Soil samples will be collected from within the conductor casing. The drill hole below the conductor casing will be approximately 3.5 to 5.5 inches in diameter.

Only water will be circulated through the pumps and conductor casing when drilling and sampling within 15 to 20 feet of the channel bottom. For deeper drilling, the drilling fluid, consisting of a mixture of circulating water and bentonite clay, will be introduced into the conductor casing via the drill string to create a more viscous drilling fluid. The drilling fluid will pass down the center of the drill rod to the cutting face in the formation being drilled and will return up the drilled hole with the suspended cuttings. The drilling fluids and cuttings will be confined by the borehole walls and the conductor casing. Return drill fluids will pass through the conductor casing to the barge or ship deck and then through a tee connection at the head of the conductor casing into the drilling fluid recirculation tank.

With the conductor casing in place, the drilling fluids will be kept in the closed system formed by the conductor casing and a tank at the top of the hole on the barge deck and a precautionary provision of a heavy plastic sleeve over the conductor casing, which drapes into an external mud tank. This system will provide a reliable seal and prevent significant spillage of the drilling fluid into the water. The drill rod and sample rod connections will be disconnected either directly over the conductor casing or the recirculation tank. Furthermore, positive barriers consisting of hay waddles or other suitable type of spill-stoppage materials will be placed around the work area on the barge and ship decks. Drill cuttings that settle out in the recirculation tank will be collected into 55-gallon storage drums. Good work practices will be observed and maintained in containing the drilling fluid, including taking care when transferring drill cuttings from the recirculation tank to the drums. The drums will be placed adjacent to the recirculation tank. If drilling fluid or drill cuttings material accidently spill onto the barge deck outside the containment area, they will be immediately picked up with a flat blade shovel and placed either into the recirculation tank or a storage drum, and the affected area will then be cleaned and mopped. Discarded soil samples will also be placed in the storage drums.

Samples will be obtained using a combination of split spoon samples, thin-walled tubes (Shelby tubes or piston samplers), and soil coring techniques. Standard penetration tests, a process of conducting split spoon sampling, will be taken in the sandy and clayey soils, and Shelby and piston tube (push) undisturbed soil samples will be taken in soft clay soils.

Standard penetration tests are performed by dropping a 140-pound automatic hammer on the drill string to drive a sampler about 1.5 feet. This is a test conducted in short durations (a few minutes for each test) using a relatively small energy source. Vibrations from the test are minimal. The Shelby tube samples would be collected by pushing on the drill string with the weight of the drill rig, and piston samplers would be collected using hydraulic fluid pressure. No vibrations are produced from pushing tube samples. A punch core or similar soil coring technique will be utilized to retain disturbed soil samples in an inner core barrel within the drill string.

Upon completion of each hole, the borings will be grouted from the bottom of the borehole to within approximately 10 to 15 feet of the top with five percent (by weight) bentonite and 95 percent (by weight) cement grout. Water will first be introduced inside the drilled hole and circulated within the conductor casing to clear out any remaining drilling mud before grouting. Grouting of the drilled hole will be accomplished by the tremie method from the bottom upward to a depth of approximately 10 feet below the bottom of the river based on a calculated grout take volume to prevent grout migration into the river water. At completion of the grouting, the conductor casing will then be pulled out of the channel bottom to complete the overwater boring operation.

Cone penetration testing, also performed from the deck of a shallow-draft barge or ship anchored to the channel bottom by spuds as described above, consists of pushing a cone connected to a series of rods (about 1.75 inch in diameter) from the barge deck, through the water column, and into the soft sediments of the river bottom at a constant rate, allowing continuous measurements of resistance to penetration both at the cone tip and the sleeve behind the cone tip. There are no loose items or netting on the CPT rods that would entrap or snag fish.

An environmental scientist stationed on the barge or ship will observe the drilling operation to ensure that all drilling fluid and cuttings are kept and confined within the recirculation tanks and storage drums. The environmental scientist will pay special attention to the river water for the presence of colored or increasingly opaque plumes when drilling, grouting, and pulling casing. All personnel on the barge or ship will report any observations of colored plumes in the water or leaking of the drilling fluids to the Environmental Scientist. Colored plumes are an indication that material may be leaking into the water. If an unauthorized discharge is discovered by any personnel on board the barge or ship, drilling activities will cease until appropriate corrective measures have been completed. Cuttings and excess drilling fluid will be contained in drums or bins, periodically off-loaded to a land-based staging area, and disposed of at a State-approved landfill site. The overwater borings will be supervised by a licensed drilling contractor under the direction of Department of Water Resources' personnel or its contractor. An engineering geologist or an engineer will be on site at the drill rig to supervise activities at all times during the operation. An environmental scientist will be on-site during all active drilling work to monitor activities.

2.5.1.1.2.3.1 Species Exposure and Risk

As described in section 2.5.1.1.1, for construction of the NDD, CCF, HOR, and barge landings, small numbers of juvenile winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead are expected to occur at the margins of the in-water work windows, which may cause those individuals to be exposed to increased turbidity caused by the geotechnical exploration. Geotechnical activities throughout the action area are expected to cause minimal turbidity-related impacts to juvenile salmonids, but a much larger impacts to a larger proportion of adult CCV steelhead and green sturgeon migrations.

Therefore, NMFS expects that increased sediment concentrations from geotechnical activities throughout the action area will adversely affect a small proportion of juvenile steelhead and winter-, spring-, and fall-run Chinook salmon and a small proportion of adult winter- and spring-run Chinook salmon and sturgeon. NMFS expects that the effect will adversely affect some steelhead and fall-run Chinook salmon adults and some juvenile green sturgeon.

2.5.1.1.2.4 Dredging

As noted in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*, the construction phase of the proposed action includes dredging activities that can mobilize bottom substrate material, increasing concentrations of suspended sediment concentration and turbidity downstream of the project construction area, which may adversely affect listed fish.

Although mobilized sediment can injure fish, as described in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*, the proposed action includes implementation of BMPs and the following AMMs, which are expected to minimize the potential for injury during dredging activities:

- *AMM1 Worker Awareness Training;*
- *AMM2 Construction Best Management Practices and Monitoring;*
- *AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material.*

Depending on location, dredging may also use a hydraulic cutterhead dredge, which will substantially reduce the amount of resuspended materials escaping into the surrounding water column by entraining the sediment into a slurry that is transported to an upland confined disposal site.

With the implementation of BMPs and AMMs, increases in turbidity and suspended sediment levels during dredging activities will be temporary localized and unlikely to reach levels causing direct injury to anadromous fish. Because only a relatively small portion of the channel will be affected and activity will be limited to daylight hours, disruptions to migration, holding, and rearing behavior are expected to be minor.

As described above in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*, juvenile fish, because of their smaller size and reliance on shallower, nearshore waters and associated cover, are likely to respond to increased sediment concentration by avoiding or moving away from affected shoreline areas. Such behavior could result in displacement of juveniles from preferred habitat or protective cover, which may reduce growth and survival by affecting foraging success or increasing their susceptibility to predation (described further in section *2.5.1.1.6 Increased Predation Risk*). Such disruptions are expected to be brief and unlikely to adversely affect the growth of individual salmonids.

2.5.1.1.2.4.1 North Delta Intake Locations

Dredging activities are associated with the construction of the north Delta diversion intakes as proposed in the PA. The three intakes of the NDD will be constructed on the east bank of the Sacramento River between Clarksburg and Courtland RMs 41.1, 39.4, and 36.8 (Intakes 2, 3, and 5). Each intake has its own construction duration with Intakes 2, 3, and 5 each projected to take approximately 4 to 5 years for a total construction period of 7 years. The area behind the cofferdam at each intake will be dewatered, and dredging activities will proceed within the confines of the cofferdams. It is assumed that after intake construction is complete, however, the area in front of each intake will need to be dredged to provide appropriate flow conditions at the intake entrance. If required, dredging will occur during the approved in-water work window of June 1 through October 31 to minimize exposure of listed fish species to construction-related impacts on sediment-related water quality and other hazards and will be minimized to the greatest extent practicable.

Construction of intake facilities would result in temporary impacts on sediment-related water quality, which may result in adverse effects to listed fish species. It is currently estimated that up to 29.9 acres or 13,974 linear feet will be affected by construction-related dredging activities. Any dredging associated with construction activities could potentially disturb sediment, increasing sediment mobilization and turbidity downstream of the dredging activity.

2.5.1.1.2.4.1.1 Winter-run Exposure and Risk

The timing and spatial occurrence of winter-run Chinook salmon presence has been described in section *2.5.1.1.1.1 Pile Driving*.

The vast majority of both adult and juvenile winter-run Chinook salmon will use the main stem Sacramento River to enter or leave the northern Delta. Therefore, nearly all juvenile and adult winter-run Chinook salmon must pass the NDD construction site on their way to and from Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary. Juvenile winter-run Chinook salmon are present in the Delta from October through April, with peak occurrence from December through March. Beach seine and trawl data from 2006 through 2015 indicate that about two percent of a year’s juveniles would be found near the vicinity of the NDD project site in October (DJFMP). Adult winter-run Chinook salmon may be found in the Delta from November through June though only about four percent of adult passage at RBDD (about 200 RM north of NDD) occurs after May.

Exposure of winter-run Chinook salmon to construction activities at the NDD intake location will be limited by the in-water work window. Based on juvenile outmigration timing, the June 1 through October 31 in-water work window is expected to greatly reduce the exposure of winter-run Chinook salmon to dredging activities because neither juveniles nor adults are typically present during this time of year. In some years, a small proportion of the total number of winter-run Chinook salmon migrating through the construction area may occur as late as June (as adults) or as early as October (as juveniles). Although mobilized sediment can injure fish, the PA includes minimization measures and the use of BMPs during dredging, which are expected to further reduce mobilization of sediment and turbidity plumes (BA *Appendix 3F*).

Increases in turbidity and suspended sediment levels during dredging activities will be temporary and localized, unlikely to reach levels causing direct injury to anadromous salmonids. Because a relatively small portion of the channel will be affected and during daylight hours only, disruptions to migration, holding, and rearing behavior of winter-run Chinook salmon are expected to be minor. Juveniles, because of their small size and reliance on shallower, nearshore waters and associated cover, are likely to respond to dredging operations by avoiding or moving away from affected shoreline areas. This behavior could result in displacement of juveniles from preferred habitat or protective cover, which may in turn reduce growth and survival by affecting foraging success or increasing their susceptibility to predation (described further in section *2.5.1.1.6 Increased Predation Risk*). These disruptions are expected to be brief and are unlikely to adversely affect the growth of individual salmonids. Given the timing of winter-run Chinook salmon migration and the proposed in-water work window, however, NMFS expects that the sediment concentration and turbidity effects of construction dredging at the NDD intake locations will adversely affect a small proportion of individuals of Sacramento River winter-run Chinook salmon.

2.5.1.1.2.4.1.2 Spring-run Exposure and Risk

The timing and spatial occurrence of spring-run Chinook salmon presence has been described in section *2.5.1.1.1 Acoustic Stress*.

Juvenile spring-run Chinook salmon may be present in the north Delta from November to June. It is very unlikely, however, for spring-run Chinook salmon to be present during the June 1 through October 31 dredging activities at the NDD intake location because the majority (greater than 98 percent) of juveniles have outmigrated by the end of May. In some years, a few remaining fish may be migrating in early June, but the use of nearshore areas by juvenile salmon is generally reduced by June because most juveniles are large, actively migrating smolts that are known to move rapidly through the Delta and estuary during their seaward migration (Williams 2006). Adult spring-run Chinook salmon are present in the Delta from January to March. Therefore, they are not expected to be present during the dredging activities at the NDD intake location because they would have migrated through much earlier than the work window start date of June 1.

As described for winter-run Chinook salmon, increases in sediment concentration during dredging will be temporary and localized, affecting a small portion of the channel, and will potentially cause juveniles to be displaced from preferred habitat or protective cover, affecting foraging success or increasing susceptibility to predation. Because of the potential for juveniles migrating in June to be exposed to dredging activities, NMFS expects that the increased sediment concentration and turbidity effects of construction dredging at the NDD intake locations will adversely affect a small proportion of individual CV spring-run Chinook salmon each year of the construction period. Adverse effects may be limited to behavioral modifications, which could result in increased risk of predation (described further in section *2.5.1.1.6 Increased Predation Risk*).

2.5.1.1.2.4.1.3 Steelhead Exposure and Risk

The timing and spatial occurrence of CCV steelhead presence has been described in section *2.5.1.1.1 Acoustic Stress.*

In summary, juvenile CCV steelhead are present in the NDD intake locations from November through June, with peak occurrence from January through March. It is unlikely that more than one to two percent of the annual juvenile population would be present at the NDD location during the June to October work window. In some years, a few remaining fish may be migrating downstream in early June, or in September and October, and this is typically in response to transient flow increases in the river, such as occurs with fall storms.

Adult CCV steelhead presence has previously been described in section 2.5.1.1.1 Acoustic Stress.

In summary, adult CCV steelhead begin to migrate upriver into the Sacramento River from the Delta in June, with increasing numbers of fish arriving from August through September, before tapering off in October and November. Peak migration (approximately 69 percent of annual run) occurs in September and October, and up to 83 percent of the adult population is expected to move upriver during the in-water work window of June 1 to October 31.

As described for winter-run Chinook salmon, increases in sediment concentration during dredging will be temporary and localized, affecting a small portion of the channel, and will potentially cause juveniles to be displaced from preferred habitat or protective cover, affecting foraging success or increasing susceptibility to predation. Because of the potential for juvenile steelhead migrating in June, September, and October to be exposed to dredging activities, NMFS expects that the increased sediment concentration and turbidity effects of construction dredging at NDD intake locations will adversely affect a small proportion of individual juvenile CCV steelhead each year of the construction period. Adverse effects may be limited to behavioral modifications, which could result in increased risk of predation of juvenile CCV steelhead (described further in section *2.5.1.1.6 Increased Predation Risk*).

A large fraction of the annual adult upstream migration has the potential to be affected by sediment resuspension related to dredging actions. NMFS expects, however, that adult steelhead will either move away volitionally from the turbidity plume into more suitable waters or move rapidly upstream through the area of increased turbidity to find more suitable waters. In either case, exposure to elevated suspended sediment concentrations is expected to be brief and not result in any demonstrable adverse physical or behavioral effects. This is due to the relatively small area impacted by dredging in front of the new intakes and the minimization measures and uses of BMPs during dredging, which are expected to further reduce mobilization of sediment and turbidity plumes. Therefore, NMFS expects that the increased sediment concentration and turbidity effects of construction dredging at the NDD intake locations will adversely affect a few adult CCV steelhead.

2.5.1.1.2.4.1.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Spawning adults migrate through the Delta between the ocean and upstream spawning habitats during the early spring, summer, and fall months, whereas juvenile sDPS green sturgeon are present throughout the Delta during every month of the year. NMFS has determined that both juvenile and spawning or post-spawn adult sDPS green sturgeon may be present in the action area during the June 1 through October 31 in-water work window owing to their widespread and year-round presence in the waters of the north Delta. They could therefore become exposed to turbidity plumes and elevated concentrations of suspended sediment resulting from dredging operations in the vicinity of the NDD during that time.

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids by having their feeding behavior disrupted, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species evolutionarily adapted for life in turbid flowing waters. They may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food due to sedimentation of benthic habitat would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects. Given the potential presence of several life-stages of green sturgeon at the NDD intake locations during the work window, NMFS expects that the increased sediment effects of dredging at the NDD intake site will adversely affect a few adult and some juvenile and sub-adult green sturgeon.

2.5.1.1.2.4.1.5 Fall/Late fall-run Exposure and Risk

Fall-run Chinook Salmon

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run Chinook salmon enter the San Francisco Bay in June and immigrate through the north Delta between July and December (Vogel and Marine 1991), with a peak in October.

Juvenile fall-run Chinook salmon will be exposed to increased sedimentation from NDD dredging during June through August. This conclusion is based on the temporal overlap between Sacramento trawl catches of fall-run Chinook salmon juveniles (December through August) and the June through October work window.

Fall-run Chinook salmon adults are likely to be exposed to increased sedimentation due to dredging at the NDD. Adult fall-run Chinook salmon immigration past the NDD construction site will occur from July through December (Vogel and Marine 1991). NDD dredging will occur from June through October. Therefore, adult fall-run Chinook salmon will overlap in time and space with NDD dredging from July through October. The overlap will occur during peak immigration (October).

Exposed late fall-run Chinook salmon will be subject to physical and behavioral responses identified in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. Increases in turbidity and suspended sediment levels during dredging activities will be temporary and localized, unlikely to reach levels causing direct injury to anadromous salmonids. Because a relatively small portion of the channel will be affected and during daylight hours only, disruptions to migration, holding, and rearing behavior of fall-run Chinook salmon are expected to be minor.

Juveniles, because of their small size and reliance on shallower, nearshore waters and associated cover, are likely to respond to dredging operations by avoiding or moving away from affected shoreline areas. This behavior could result in displacement of juveniles from preferred habitat or protective cover, but the disruptions are expected to be brief and over a limited area, so they are unlikely to reduce juvenile growth.

Given that June through August represents a period of low occurrence of fall-run Chinook salmon juveniles in the Sacramento trawl, some individuals are expected to experience adverse effects, but the overall exposure and risk to that life stage would likely be minimal. Though the peak adult migration month of October occurs during the work window, the overall risk to adults is also expected to be minimized due to the temporary and localized nature of dredging. NMFS expects that the increased sediment effects of dredging at the NDD intake site will adversely affect a small proportion of juvenile and some adult fall-run Chinook salmon.

Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon are present in the Delta from July through September. Adult late fall-run Chinook salmon enter the San Francisco Bay in fall and are present through April (Vogel and Marine 1991).

Juvenile late fall-run Chinook salmon will be exposed to increased sediment concentration and turbidity caused by PA dredging at the NDD intake locations from July through September. This conclusion is based on the temporal overlap between Sacramento trawl catches of fall-run Chinook salmon juveniles (July through September; November through January) and the June through October NDD pile driving work window.

Late fall-run Chinook salmon adults will not be exposed to increased sediment concentration and turbidity caused by PA dredging at the NDD intake locations, except for the very end of the immigration period. Adult late fall-run Chinook salmon immigration past the NDD construction site will occur from the end of October through early April (Vogel and Marine 1991). NDD dredging will occur from June through October. Therefore, adult late fall-run Chinook salmon will overlap in time and space with NDD pile driving only during the end of October.

Exposed late fall-run Chinook salmon will be subject to physical and behavioral responses identified in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*. Reduced fitness due to stress related to turbidity plumes from the pulsed sediment plumes is expected. Given that there is a three-month period in which late fall-run Chinook salmon juveniles will be exposed to increased sediment concentration and turbidity caused by PA dredging at the NDD intake locations, an adverse effect to individuals of this life stage is expected. Additionally, adverse effects to adults are expected, but the risk is minimal given the limited exposure. NMFS expects that the increased sediment effects of dredging at the NDD intake site will adversely affect some juvenile and adult late fall-run Chinook salmon.

2.5.1.1.2.4.2 Clifton Court Forebay

Dredging at CCF during construction is likely to result in increased sediment mobilization and turbidity, which has the potential to adversely affect listed fish. Construction at CCF includes dredging the existing CCF area, as well as excavating the expanded CCF (590 acres to the southeast) to design depths of negative 8 feet for north CCF (NCCF) and negative 10 feet for south CCF (SCCF). Although the in-water work window is restricted to July 1 through

November 30 of each year of construction, the partition sheet pile dike will be closed off in the late summer months, which will then isolate the NCCF. Because water temperatures will be too warm for salmonids in the summer months, they are not expected to be present in the NCCF once it is isolated. Fish capture and relocation will then take place in the NCCF. Dredging will begin once fish are removed and the area is dewatered; therefore, listed fish are not expected to be adversely affected by dredging in the NCCF.

As with current operations, fish will continue to be entrained into the existing portion of SCCF throughout the years of construction via the radial gates at Old River. As described in the PA and information provided by DWR, the existing portion of SCCF will begin to be systematically dredged within a silt curtain isolating a circumference of approximately 200 acres of resulting increased sediment and turbidity from the rest of the area. This method of dredging is expected to greatly minimize adverse effects of mobilized sediment and increased turbidity to fish, although any fish present may experience some disturbance or injury. Dredging will only occur within the in-water work window each year of construction, which will greatly minimize the risk of listed salmonid presence. Fish may, however, enter the area as water temperatures start to cool (especially October and November). Green sturgeon may be present year-round. The expanded area of SCCF will be excavated to design depth before opening the berm to connect with the existing SCCF portion.

Recognizing that design of these modifications is still in an early stage, DWR, Reclamation, NMFS, CDFW, and USFWS have agreed to ongoing collaborative efforts to ensure that the final design and construction procedures for CCF minimize adverse effects to listed species to the extent practicable. Accordingly, representatives from each of these agencies will participate in a Clifton Court Forebay Technical Team (CCFTT). Additionally, the proposed construction at CCF includes implementation of the appropriate BMPs and AMMs identified in BA *Appendix 3F*, which are expected to minimize adverse effects to species.

2.5.1.1.2.4.2.1 Chinook Salmon Exposure and Risk

The timing and spatial occurrence of all salmonids has been described in section *2.5.1.1.1.1 Pile Driving*.

Limiting dredging activities within CCF to the July 1 through November 30 work window is expected to minimize exposure to salmonid species because:

- Juvenile winter-run Chinook salmon are present in the CCF from November to April. Adult winter-run are present in the Delta between November and June, but are unlikely to be found in CCF because it is outside of their main upstream migratory route.
- Juvenile spring-run Chinook salmon are expected to be present in CCF from February to June, while adult spring-run are present in the Delta between January and March.
- Juvenile fall- and late fall-run Chinook salmon are expected to be present in CCF from January through June. A portion of juvenile late fall-run Chinook salmon will be present during July to November. Although adult fall-run will be migrating through the action area from July through December, only a small portion of the Central Valley population is expected to pass near CCF. Adult late fall-run Chinook salmon are not expected to be present during construction activities.

Continued operation of CCF throughout the construction period, however, increases the risk of potential entrainment of listed fish species into CCF during construction, creating a potential for adverse effects to listed fish from dredging activities. With implementation of the AMMs and in-water work window, the in-water construction activities would result in mostly temporary, localized increases in turbidity and suspended sediment, but any fish present may be subject to behavioral modifications as described in section *2.5.1.1.6 Increased Predation Risk*. The effects on all adult and juvenile salmonids would likely be limited to harassment of individuals that encounter turbidity plumes.

Given the extension of the work window into November and potential presence of juvenile winter- and spring-run Chinook salmon in the area, NMFS expects the increased sediment concentration effects of dredging at CCF to adversely affect a small proportion of juvenile winter- and spring-run Chinook salmon. Exposed late fall-run Chinook salmon will be subject to physical and behavioral responses identified in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress* such as reduced fitness due to stress related to turbidity plumes. Given that late fall-run Chinook salmon juveniles will be present during the July through November work window, NMFS expects that the increase in sediment concentration and turbidity caused by dredging activities at CCF will adversely affect some juvenile late fall-run Chinook salmon.

2.5.1.1.2.4.2.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the Clifton Court location has been described in section *2.5.1.1.1 Acoustic Stress*.

Less than one percent of the annual juvenile emigration is expected to occur at the CCF during the proposed work window (July 1 through November 30). The majority of juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities. It is expected that the timing of adult presence at the CCF location will be later than that observed for the North Delta due to its southern Delta location, and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with the majority of the population passing through the Delta from November to January. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through November with the proposed in-water work window.

Because the dredging of CCF will occur only during the in-water work window (July 1 through November 30), it is expected that adult steelhead will be the predominant life stage affected by dredging in CCF due to the overlap in the dredging work window and the upstream migration of adult steelhead. Few juvenile CCV steelhead are expected to be affected by the dredging actions in CCF due to their later migration period.

Because the majority of the juvenile steelhead emigration occurs after the end of the dredging action, NMFS expects that the sediment effects of dredging at the CCF will adversely affect a small proportion of juvenile steelhead. Adult steelhead migration timing overlaps with the work window at CCF, especially given the extension to November for in-water work. Therefore, NMFS expects that the sediment effects of dredging at the CCF will adversely affect some adult steelhead.

2.5.1.1.2.4.2.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk.*

Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. NMFS has determined that juvenile, adult, and sub-adult sDPS green sturgeon will be exposed to elevated concentrations of suspended sediment and turbidity in CCF during the in-water construction period due to their widespread and year-round presence in the waters of the Delta.

Limiting dredging activities to the in-water work window of July 1 through November 30 will avoid the peak upstream migration period of adult green sturgeon transiting the action area (late February to early May) to upstream spawning habitats, although post-spawning adults returning to the ocean, sub-adults, and juveniles may be present in the Delta during the late summer and fall months. They are therefore potentially exposed to increases in turbidity and suspended sediment in CCF during the in-water work window. Salvage of green sturgeon generally peaks in the summer although few have been present at the CVP/SWP in recent years (National Marine Fisheries Service 2015b). A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta. (National Marine Fisheries Service 2015b).

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids by having their feeding behavior disrupted, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species evolutionarily adapted for life in turbid flowing waters. They may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food due to sedimentation of benthic habitat would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects and the low quality of existing habitat in CCF and adjacent south Delta channels.

Given the known presence of juvenile and sub-adult green sturgeon in the Delta during the in-water work window, NMFS expects that the sediment effects of dredging at the CCF will adversely affect some juvenile and sub-adult green sturgeon. Because adult green sturgeon are not present at the CCF from August through November, NMFS expects that the sediment effects will not adversely affect adult green sturgeon.

2.5.1.1.2.4.3 HOR Gate

Dredging activities are associated with constructing and installing the HOR gate as proposed in the PA. Dredging to prepare the channel for construction of the HOR gate will occur along 500 feet of channel, from150 feet upstream to 350 feet downstream of the proposed gate location. A total of up to 1,500 cubic yards of material is expected to be dredged. Dredging will last approximately 15 days and will be performed within the August 1 through October 31 in-water work window for this location. Sediment mobilization and increased turbidity in Old

River and the San Joaquin River downstream of the activity is likely and therefore any fish present may be adversely affected.

As described in section *2.5.1.1.2.4.1 North Delta Intake Locations*, implementation of the appropriate BMPs and AMMs is proposed to minimize potential adverse effects to fish because of dredging activities.

2.5.1.1.2.4.3.1 Winter-run Species Exposure and Risk

The timing and spatial occurrence of juvenile and adult winter-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving*.

Juveniles are present in the Delta from October through April, while adults are present in the Delta from November through June. Because the HOR gate is on a distributary of the San Joaquin River far from the main winter-run Chinook salmon migration corridor (i.e., the Sacramento River), it is highly unlikely that winter-run Chinook salmon would be found in the vicinity of the gate. Additionally, the in-water work window for the HOR gate is August 1 through October 31, so the potential for dredging-induced turbidity is not expected to coincide with winter-run Chinook salmon presence. Given the timing and location of winter-run Chinook salmon presence and migration compared to the proposed in-water work window, NMFS expects that the sediment concentration and turbidity effects of construction dredging at the HOR gate would not adversely affect winter-run Chinook salmon.

2.5.1.1.2.4.3.2 Spring-run Exposure and Risk

The timing and spatial occurrence of juvenile and adult spring-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving*.

Both San Joaquin River basin spring-run Chinook salmon adults and any straying adults from the Sacramento River basin will most likely already be staging for spawning in upriver locations by August and are not expected to be migrating through the vicinity of the HOR during the August 1 through October 31 work window. Although there is some uncertainty due to lack of monitoring data regarding the timing of outmigrating juvenile spring-run Chinook salmon in the San Joaquin River basin, NMFS assumes that these fish exhibit similar emigration patterns to the Sacramento River basin populations, and, therefore, yearling smolt spring-run Chinook salmon may be present in the vicinity of the HOR gate in October, though likely in very few numbers. NMFS therefore expects that the sediment concentration and turbidity effects of construction dredging at the HOR gate will adversely affect a very small proportion of spring-run Chinook salmon. Adverse effects are likely limited to behavioral modifications, which could result in increased risk of predation (as described in section *2.5.1.1.6 Increased Predation Risk*).

2.5.1.1.2.4.3.3 Steelhead Exposure and Risk

The timing of CCV steelhead at the HOR gate location has been described in section *2.5.1.1.1.1 Pile Driving*.

In summary, juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Because dredging activities are limited to August 1 through October 31, a minimal amount of temporal overlap with the presence of juvenile CCV steelhead is expected. Less than one to two percent of the annual juvenile emigration from either the Sacramento or San Joaquin River basin is expected to occur during the proposed work window. San Joaquin River basin juvenile CCV steelhead presence is expected to peak in April and May, but their abundance is considerably lower than that of steelhead originating from the Sacramento River basin. It is not expected that that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate.

Adult CCV steelhead presence has previously been described in section *2.5.1.1.1.1 Pile Driving*. Adult CCV steelhead from the Sacramento River basin are not expected to be present at the HOR gate location. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. Because dredging at the HOR gate occurs during August through October, only adult steelhead migrating into the San Joaquin River basin during these months will be affected. It is anticipated that only a small proportion of the annual adult upriver migration will overlap with the dredging associated with the HOR gate installation.

Because of the timing of the dredging activities at the HOR gate location and the presence of only a small percentage of the juvenile population at this time, NMFS expects that increased sediment will adversely affect a small proportion of juvenile steelhead. Because adult steelhead from the San Joaquin River basin begin migration in September or October and generally peak in presence in November, NMFS expects that increased sediment will adversely affect some adult San Joaquin River steelhead.

2.5.1.1.2.4.3.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Despite the uncertainty and variability associated with Delta residence time by life stage, juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta during every month of the year, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta. Because of the widespread and year-round presence of juvenile and sub-adult sDPS green sturgeon in the waters of the Delta, these life stages could be present in the vicinity of the HOR gate and could be exposed to increased suspended sediment concentrations and turbidity from dredging operations associated with construction during the August 1 through October 31 in-water construction period.

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids by having their feeding behavior disrupted, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species evolutionarily adapted for life in turbid flowing waters. They may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food due to sedimentation of benthic habitat would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects. Given the potential presence of several life stages of green sturgeon at the HOR gate location during the work window, NMFS expects that the increased sediment effects of dredging at the HOR gate site will adversely affect a small proportion of adult and some juvenile and sub-adult green sturgeon.

2.5.1.1.2.4.3.5 Fall/Late fall-run Exposure and Risk

Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult fall-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving.*

Juvenile fall-run Chinook salmon do not occur in the Delta during the August through October construction window and are not are likely to be exposed to increased sediment concentration and turbidity.

Adult fall-run Chinook salmon from the San Joaquin basin will be immigrating to their natal spawning grounds from September through December. Given that HOR gate construction site will be adjacent to the San Joaquin River, some immigrating adults will likely be in the construction area during the August through October construction period. Fall-run Chinook salmon adults are likely to be exposed to increased sediment concentration and turbidity due to PA dredging at the HOR gate.

Adult Sacramento River fall-run Chinook salmon, particularly hatchery-origin fish, may be present at the HOR gate location. Naturally produced Chinook salmon adults have low stray rates relative to hatchery-produced fish, particularly when hatchery releases are made off site (Keefer and Caudill 2014). As such, fall-run Chinook salmon adults produced naturally in the Sacramento River basin have a low probability of straying into the HOR gate area, whereas fish produced at Coleman National Fish Hatchery, Feather River Hatchery, and Nimbus Hatchery on the American River are more likely to stray into Old River and experience HOR gate dredging stressors.

Because juvenile fall-run Chinook salmon are not present during dredging activities, NMFS expects that the increased sediment concentrations would not adversely affect juvenile fall-run Chinook salmon. Given the temporal and spatial overlap between fall-run Chinook salmon adults and the short-term duration of dredging activities, NMFS expects that increased sediment concentrations due to dredging at HOR gate will adversely affect some fall-run Chinook salmon adults.

Late Fall-run Chinook Salmon

Late fall-run Chinook salmon occur in the Sacramento River basin, but not the San Joaquin River basin. Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the August through October construction window. Therefore these fish are expected to be exposed to the effects of dredging activities at the HOR gate location.

While stray late fall-run Chinook salmon adults occur occasionally in the San Joaquin River near the HOR gate location, the likelihood of occurrence is low. Nearly all Coleman National Fish Hatchery late fall-run Chinook salmon immigrate to the Sacramento River basin where they originated (Kormos et al. 2012). Additionally, the October through April timing of adult immigration only slightly overlaps with the window for dredging activities at HOR gate. Therefore there is a very low probability that adult late fall-run Chinook salmon will overlap in time and space with stressors produced by dredging at the HOR gate.

Given the temporal and spatial overlap between late fall-run Chinook salmon adults and the short-term duration of dredging activities, NMFS expects that the increased sediment concentrations associated with dredging activities at the HOR gate will adversely affect a small proportion of juvenile late fall-run Chinook salmon. Given the low probability of occurrence of late fall-run Chinook salmon adults at the HOR gate location, NMFS expects that the increased sediment would not adversely affect adult late fall-run Chinook salmon.

2.5.1.1.2.4.4 Barge Routes and Landings

Dredging associated with barge operations can be expected during the construction activity period of the proposed action. Barge landings are distributed over a broad area of the San Francisco estuary. The Sacramento-San Joaquin Delta barge routes will cover nearly 100 miles of waterways from San Francisco to the Port of Stockton and landing locations at the NDD intake location and CCF.

During the five to six years of construction, barge landing sites (described in section *2.5.1.1.1.1.4 Barge Landing Locations*) and the barge routes themselves (described in section *2.5.1.1.1.2 Barge Traffic*) may need to be periodically dredged of collected sediment to adequate depths to maintain passage. Although dredging at barge landings and along barge routes was included in the BA, NMFS and DWR jointly determined the assumptions on frequency and need for this dredging activity, which are based on professional judgment. The assumptions include initial dredging at both barge landings and along barge routes as needed and up to two additional spot dredging actions at barge landings and along barge routes as needed. NMFS also assumes that the in-water work window for dredging activities associated with barge operations will be the same as that used for construction at the barge landings (August 1 through October 31). This work window is expected to minimize exposure to fish.

Dredging operations that occur when fish are present are expected to result in exposure to elevated sediment concentrations, which may result in adverse effects to fish. Adverse effects may be limited to fish behavior modifications or may result in direct injury (described in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*). The proposed action includes implementation of BMPs and AMMs, which are expected to minimize the potential for injury during dredging activities (BA Appendix 3F).

2.5.1.1.2.4.4.1 Winter-run and Spring-Run Chinook Salmon Exposure and Risk

Detailed timing and spatial occurrence of winter-run and spring-run Chinook salmon presence in the Delta has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Limiting dredging activities of the PA within the Delta to the August 1 through October 31 work window is expected to minimize exposure to these runs of Chinook salmon, because

- Winter-run Chinook salmon juveniles are present in the Delta from October through April, with about two percent of a year’s juveniles found in the north Delta in October (DJFMP). Adult winter-run Chinook salmon are present in the Delta from November through June.
- Spring-run Chinook salmon juveniles may be present in the north Delta from November to June, with the majority (greater than 98 percent) of juveniles having outmigrated by the end of May. Adult spring-run Chinook salmon are present in the Delta from January to March as they begin to migrate upstream into the Sacramento River or San Joaquin River basin.

NMFS therefore expects that sediment exposure effects of dredging at barge landings and barge access routes are unlikely to adversely affect individual winter-run and spring-run Chinook salmon throughout the Delta.

2.5.1.1.2.4.4.2 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of CCV steelhead presence in the Delta has previously been described in section *2.5.1.1.1.1 Pile Driving*.

The majority of adult steelhead enter the Delta region from June through November, with a peak in September. Low levels of adult CCV steelhead continue to emigrate upriver through March. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. Steelhead smolts begin to enter the northern Delta from the Sacramento River as early as September through December, but do not substantially increase in numbers until February and March. Less than one percent of the juvenile population is expected to be present during September and October. Downstream migration of San Joaquin River basin steelhead smolts into the Delta peaks in April and May.

Because of the potential for juvenile steelhead migrating in June, September, and October to be exposed to dredging activities, NMFS expects that the increased sediment concentration and turbidity effects of dredging at the barge landing locations and along the proposed barge routes will adversely affect a small proportion of individual juvenile CCV steelhead. Adverse effects may be limited to behavioral modifications, which could result in increased risk of predation of juvenile CCV steelhead (described further in section *2.5.1.1.6 Increased Predation Risk*). Given that the in-water water work window of August 1 through October 31 overlaps with a substantial proportion of the adult upstream migration, NMFS expects that increase in sediment concentration will adversely affect some adult CCV steelhead from both the Sacramento and San Joaquin River basins.

2.5.1.1.2.4.4.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. Because of the widespread and year-round presence of juvenile, adult, and sub-adult sDPS green sturgeon in the Delta, NMFS expects that these life stages would be exposed to turbidity plumes and elevated concentrations of suspended sediment resulting from dredging operations at barge landings and along barge routes during the in-water work window from August 1 through October 31.

The potential for increased sediment concentrations and turbidity because of dredging operations associated with the barge landings and travel routes is expected to have an effect on juvenile, sub-adult and adult sDPS green sturgeon. Multiple barge landings sited in the north, central, and south Delta occur on waterways that are occupied by juvenile and sub-adult life stages of sDPS green sturgeon rearing in the Delta during every month of the year.

Additionally, the annual spawning migrations of adult green sturgeon between the ocean and upstream spawning habitats overlap with the projected routes of barge traffic anticipated between the Golden Gate Bridge in San Francisco and Chipps Island.

Therefore all juvenile, sub-adult, and spawning or post-spawn adult sDPS green sturgeon will have some level of exposure to increased sediment concentrations resulting from dredging operations at the multiple barge landings and routes located throughout the Delta and San Francisco Estuary. A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon because of their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats.

The adverse effects to fish typically associated with elevated concentrations of suspended sediment in the water column has been generally described in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*, although it is unclear to what extent exposed green sturgeon will be affected. No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. It is possible that higher concentrations of suspended sediment and turbidity in the Delta may interfere with normal sturgeon feeding and migratory behavior, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species, evolutionarily adapted for life in turbid flowing waters, and may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food because of sedimentation of benthic habitat following a dredging episode would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects.

Given the known presence of juvenile, sub-adult, and adult green sturgeon in the Delta during the in-water work window, NMFS expects that the sediment effects of dredging at the barge landings and along barge routes will adversely affect some juvenile, sub-adult, and adult green sturgeon.

2.5.1.1.2.4.4.4 Fall/Late fall-run Exposure and Risk

Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult fall-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving.*

Juvenile fall-run Chinook salmon do not occur in the Delta during the August through October construction window. Therefore this life stage is not expected to be exposed to increased sediment concentration and turbidity due to dredging at barge landing locations and barge routes.

The fall-run Chinook salmon adult immigration period for both the San Joaquin River basin (September through December) and the Sacramento River basin (July through December) overlap with the August through October dredging period. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by fall-run Chinook salmon adults from both the Sacramento and San Joaquin river basins. Given the spatial and temporal overlap, fall-run Chinook salmon adults are expected to be exposed to stressors produced by this activity. A higher level of exposure is anticipated for fall-run Chinook salmon originating in the San Joaquin River basin because most barge routes will occur in the Stockton

DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF.

Given the lack of exposure for juvenile fall-run Chinook salmon, NMFS expects that the increased sediment concentration and turbidity caused by dredging at barge landing locations and along barge routes would not adversely affect juvenile fall-run Chinook salmon. Given the temporal and spatial overlap of fall-run Chinook salmon adults and the in-water dredging activity timing, however, NMFS expects that increased sediment concentrations will adversely affect some fall-run Chinook salmon adults.

Late Fall-run Chinook Salmons

Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the August through October in-water work window for dredging. Juveniles are therefore likely to be exposed to increased sediment concentration and turbidity due to dredging at barge landing locations and barge routes.

The timing of adult immigration of late fall-run Chinook salmon (end of October through beginning of April) only slightly overlaps with the window for dredging at barge landings and routes (August through October). Adult late fall-run Chinook salmon at the very beginning of the spawning run (i.e., end of October) are expected to be adversely affected by dredging at the barge routes and landings.

Given the exposure for juvenile late fall-run Chinook salmon, NMFS expects that the increased sediment concentration and turbidity caused by dredging at barge landing locations and along barge routes will adversely affect a few juvenile late fall-run Chinook salmon. Because early adult migrants may be present during the work window, NMFS expects that the increased sediment concentration will adversely affect some adult late fall-run Chinook salmon.

2.5.1.1.3 Contaminant Exposure

The proposed action includes activities that could increase the exposure of fish to harmful contaminants. Chemical forms of water pollution are a major cause of freshwater habitat degradation worldwide. There are many sources of contaminants, and these reflect past and present human activities and land use (Scholz and McIntyre 2015). Contaminants are typically associated with areas of urban development, agriculture, or other anthropogenic activities (e.g., mercury contamination as a result of gold mining or processing). Organic contaminants from agricultural drain water, urban and agricultural runoff from storm events, and high trace element (i.e., heavy metals) concentrations may deleteriously affect early life-stage survival of fish in the Central Valley watersheds (National Marine Fisheries Service 2011, 2013).

Many freshwater taxa in the Central Valley are in noticeable decline. This notably includes ESA-listed species and their designated critical habitat, which are susceptible to contaminants, many of which interact with other stressors such as pathogens to cause mortality, reproductive failure, and other losses to individual fitness. Many ESA-listed fish species are highly mobile and traverse hundreds of kilometers of freshwater habitat from the Sacramento-San Joaquin River Delta on their migration path to and from the ocean (Quinn 2005). The degree of sediment mobility and the increased contaminant exposure due to aggregated impacts of pollution from resuspension of sediment by various actions such as large vessel operations (Macneale et al.

2014) within the action area are a particularly important consideration for listed species and their designated critical habitats.

Areas with low human impacts frequently have low contaminant burdens and, therefore, lower levels of potentially harmful toxicants in the aquatic system (Relyea 2009). Legacy contaminants such as mercury, methyl mercury, polychlorinated biphenyls (PCBs), heavy metals, and persistent organochlorine pesticides, however, continue to be found in watersheds throughout the Central Valley. For example, persistent organic pollutants such as PCBs disrupt immune system function in exposed fish, thereby rendering exposed fish more susceptible to disease. PCBs are considered persistent pollutants because they resist degradation in the environment, by processes that are either biotic (e.g., microbial breakdown) or abiotic (e.g., photolysis in response to sunlight). They accumulate in sediments and can be resuspended and redistributed in aquatic habitat by dredging and similar forms of human disturbance.

Metals, PCBs, and hydrocarbons (typically oil and grease) are common urban contaminants that are introduced to aquatic systems via nonpoint-source stormwater drainage, industrial discharges, and municipal wastewater discharges. Many of these contaminants readily adhere to sediment particles and tend to settle out of solution relatively close to the primary source of contaminants. PCBs are persistent, adsorb to soil and organic matter, and accumulate in the food web. Lead and other metals also will adhere to particulates and can bioaccumulate to levels sufficient to cause adverse biological effects. Mercury is also present in the Sacramento River system and could be sequestered in riverbed sediments. Hydrocarbons biodegrade over time in an aqueous environment and do not tend to bioaccumulate or persist in aquatic systems. This suite of contaminants could pose a risk to listed fish if resuspension of contaminated sediments increases exposure.

Resuspended sediment can expose legacy contaminants that have previously been buried in the waterway's bottom sediment. Sediment is usually considered a sink for anthropogenic contaminants in marine and freshwater environments. Regardless of whether discharges originate from air, rivers, urban or agriculture runoff, or effluents from wastewater treatment plants, contaminants such as heavy metals and organic pollutants are typically scavenged by suspended, fine grained, mineral and organic particles in the aqueous environment and will eventually settle out of the water column when quiescent hydrodynamic conditions prevail (Lepland et al. 2010, Roberts 2012).

Benthic and infauna species are primarily exposed to these contaminated sediment horizons. When sediment is resuspended, the bound contaminants are remobilized into the water column and become bioavailable to an additional assemblage of aquatic species through chemical processes that change their charge and chemical properties (e.g. oxidation in the aerobic water). While most of the material will likely settle out of suspension in close proximity to the disturbance, some of it may be transported considerable distances from the point of disturbance due to tidal or river currents. The resuspended material can be thought of as a pulsed disturbance resulting in episodic (pulsed) exposures of organisms to the contaminants. To fully understand the responses of exposed organisms, one must know not only the toxicological effects of the contaminant exposure to different organisms and the aquatic community, but also the frequency, magnitude, and duration of the disturbance event (Roberts 2012).

In 2010 the EPA listed the Sacramento River as impaired under the Clean Water Act, section 303(d), due to high levels of pesticides and heavy metals. The U.S. Army Corps of Engineers has identified polycyclic aromatic hydrocarbons (PAHs), organophosphates, chlorinated herbicides, ammonia, oil, grease, glyphosate, a-amino-3-hydroxy-5-methyl-4-isoxazolepro-pionate (i.e., AMPA), dioxin, heavy metals, and other constituents as potential contaminants within the action area. Some of these contaminants have been found to cause effects of acute and chronic stress that are sublethal and lethal to salmonids (Allen and Hardy 1980). Although most of these contaminants are at low concentrations in the food chain, they continue to work their way into the base of the food web, particularly when sediments are disturbed and previously entombed compounds are released into the water column.

If bioaccumulative contaminants such as organochlorines are released as a result of dredging they biomagnify in aquatic food webs. That is, they become proportionately more concentrated at higher trophic levels. Consequently, they present a greater risk to fish that feed at or near the top of aquatic food webs. Disturbing benthic sediments through dredging and dredge material disposal, as well as through the mechanisms of effluent return flows from dredged material placement sites, is expected to mobilize and redistribute a variety of contaminants in the water column. If contaminants are released during dredging or dredged material disposal activities, their effects may be subtle and difficult to directly observe.

Exposure to contaminated food sources and bioaccumulation of contaminants from feeding on them may create delayed sublethal effects that negatively affect the growth, reproductive development, and reproductive success of listed anadromous fishes, thereby reducing their overall fitness and survival (Laetz et al. 2009). The effects of bioaccumulation are of particular concern as pollutants can reach concentrations in higher trophic level organisms (e.g., salmonids) that far exceed ambient environmental levels (Allen and Hardy 1980).

Bioaccumulation may therefore cause delayed stress, injury, or death as contaminants are transported from lower trophic levels (e.g., benthic invertebrates or other prey species) to predators long after the contaminants have entered the environment or food chain. Many contaminants lack defined regulatory exposure criteria that are relevant to listed salmonids and yet may have effects on salmonids (Ewing 1999). It follows that some organisms may be negatively affected by contaminants while regulatory thresholds for the contaminants are not exceeded during measurements of water or sediments.

Sublethal or nonlethal effects indicate that death is not the primary toxic endpoint. Rand (1995) stated that the most common sublethal endpoints in aquatic organisms are behavioral (e.g., swimming, feeding, attraction-avoidance, and predator-prey interactions), physiological (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes. Some sublethal effects may result in indirect mortality, for example, when a fish already stressed due to toxicity encounters an additional stressor and the combination of those causes death. Changes in certain behaviors, such as swimming or olfactory responses, may diminish the ability of listed fish to find food or escape from predators and may ultimately result in death. Some sublethal effects may have little or no long-term consequences to the fish because they are rapidly reversible or diminish and cease with time. Individual fish of the same species may exhibit different responses to the same concentration of toxicant. In addition, the individual condition of the fish can significantly influence the outcome of the toxicant exposure. Fish with greater energy stores will be better able to survive a temporary decline in foraging ability or have sufficient metabolic stores to swim to areas with better environmental conditions. Fish that are already stressed are more susceptible to the deleterious effects of contaminants and may succumb to toxicant levels that are considered sublethal to a healthy fish.

Exposure to sublethal levels of contaminants has been shown to cause serious implications for salmonid health and survival. Studies have shown that low concentrations of commonly available pesticides can induce significant sublethal effects on salmonids. Scholz et al. (2000) and Moore and Waring (1996) have found that diazinon interferes with a range of physiological biochemical pathways that regulate olfaction, negatively affecting homing, reproductive, and anti-predator behavior of salmonids. Waring and Moore (1997) also found that the carbofuran had significant effects on olfactory mediated behavior and physiology in Atlantic salmon (*Salmo salar*). Ewing (1999) reviewed scientific literature on the effects of pesticides on salmonids and identified a wide range of sublethal effects such as impaired swimming performance, increased predation of juveniles, altered temperature selection behavior, reduced schooling behavior, impaired migratory abilities, and impaired seawater adaptation (Sandahl et al. 2000, Baldwin et al. 2009, Laetz et al 2009, Laetz et al 2013, McIntryre et al. 2012). Other non-pesticide compounds that are common constituents of urban pollution and agricultural runoff also have the potential to negatively affect salmonids.

Pollution risks vary depending on the particular chemical, the amount transported in stormwater, and environmental persistence. Even short-term exposure to aquatic pollutants (i.e., copper) can cause acute lethality or a variety of sub-lethal adverse effects to aquatic species (Baldwin et al. 2003, Hecht et al. 2007, McCarthy 2008). Recent studies in the Pacific Northwest provide insight on the ecological impacts of stormwater, particularly in urban streams, on the growth and survival of listed coho salmon (Sandahl 2007, Feist et al. 2011, Scholz et al. 2011, Spromberg 2011). Exposure to chlorinated hydrocarbons and aromatic hydrocarbons causes immunosuppression and increased disease susceptibility (Arkoosh et al. 1994). In areas where chemical contaminant levels are elevated, disease may reduce the health and survival of affected fish populations (Arkoosh et al. 1994). Environmental stresses as a result of low water quality can lower reproductive success and may account for low productivity rates in fish.

The Southern DPS of North American green sturgeon are expected to be more vulnerable than salmonids to the negative effects of dredging due to their benthic-oriented behavior, which conceivably put them in closer proximity to the contaminated sediment horizon, although it is presently unclear if juveniles exhibit this behavior to the same extent that adults do (Presser and Luoma 2010, 2013). Their “inactive” resting behavior on substrate may potentially put them in dermal contact with contaminated sites, which can lead to lesions and the production of tumors from materials in the substrate. Sturgeon are also benthic invertebrate feeders that forage on organisms that can sequester contaminants at much higher levels than the ambient water or sediment content, such as the Asian clams *Corbicula* and *Potamocorbula* that are prevalent in the action area. The great longevity of sturgeons also places them at risk for the bioaccumulation of contaminants to levels that create physiologically adverse conditions within the body of the fish.

As noted above, the literature suggests that certain contaminants may affect the biology of salmonids. At present, regulatory thresholds are likely inadequate to account for these effects because some contaminants do not have established salmonid exposure or bioaccumulation criteria. Therefore, we expect the proposed action to have sublethal effects on listed salmonids as described above. We also anticipate green sturgeon to experience sublethal effects to the same or a greater extent than listed salmonids due to their year-round presence in the action area and dermal contact with sediment because of their benthic lifestyle. Sublethal effects may include behavioral (e.g., swimming, feeding, attraction-avoidance, and predator-prey interactions), physiological (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes.

Because of uncertainties regarding the contaminants present, however, and the concentration at these specific sites, there may be more appropriate specific measures that have not yet been defined. To address these uncertainties, Reclamation and DWR propose to work with NMFS to develop and implement a hazardous materials management plan with specific steps to monitor and measure contaminant level and type, address the containment of contaminants, and describe handling, storing, and disposing of contaminated sediments.

2.5.1.1.3.1 Pile Driving

Pile-driving activities at the north Delta diversion intake locations are described in section *2.5.1.1.1.1 Pile Driving*.

Pile driving has the potential to harm or harass salmonids and green sturgeon within the action area. Resuspension of sediments caused by pile driving may expose species to previously sequestered contaminants in the benthos, resulting in adverse effects to fish.

Although a number of compounds that may be acutely or chronically harmful to salmonids are likely present in the action area, their relative concentration is uncertain. Furthermore, the potential extent of exposure is limited. Observations and analysis of pile driving conducted in an environment similar to the Sacramento San Joaquin Delta indicate that very little resuspended sediment is generated from pile driving activities and that any potential impact is significantly less than background fluctuations in ambient water clarity over time (David Evans and Associates, Inc. 2012). Exposure to contaminants resuspended by pile driving associated with the PA is not expected to manifest as direct injury of or death to fish. Instead, it is likely that the effect of pile-driving-induced contaminant exposure will manifest as sublethal effects. Monitoring during construction activities that resuspend sediment will be important to ensure additional effects are not occurring.

2.5.1.1.3.1.1 North Delta Intake Locations

2.5.1.1.3.1.1.1 Species Exposure and Risk

Although exposure to contaminants as a result of pile driving at the NDD intake locations has potential to impact juvenile salmonids, it is not expected to result in injury or death. Also, even though timing of pile driving at NDDs (June 1 through October 31) will expose a much larger proportion of adult CCV steelhead and green sturgeon migrations, the likelihood of this level of sediment disturbance releasing contaminants is extremely unlikely. Any effects of contaminants in resuspended sediment during pile driving is expected to be limited to sublethal effects described above.

For construction at the NDD intake locations, small numbers of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead are expected to occur at the margins of the in-water work window, which may cause those individuals to be exposed to resuspended contaminants caused by pile driving. In October, about two percent of juvenile winter-run-sized Chinook salmon are expected in the vicinity of the NDD intake locations, while in June less than two percent of spring-run sized Chinook salmon and about one to two percent of steelhead could be migrating past the intake locations. About 0.8 percent of a year's juvenile fall-run sized fish would be found near the NDD intake locations in June through October (DJFMP).

Neither adult winter-run Chinook salmon nor spring-run Chinook salmon would be expected to be found in the vicinity of the NDD intake location during the in-water work window. Adult steelhead and green sturgeon may potentially be found within the Delta during any month of the year, and unlike Chinook salmon, steelhead and sturgeon can spawn more than once, so post-spawn adults have the potential to move back downstream through the Delta after completing their spawning in their natal streams. Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Adult fall-run Chinook salmon are expected to pass the NDD intake locations between July and December, with the peak of the migration in October. The timing of the adult fall-run Chinook salmon, CCV steelhead, and green sturgeon presence in the Delta has the potential to expose fish destined for the Sacramento River basin to contaminants resuspended during pile driving operations. NMFS therefore expects that increased contaminant exposure due to pile-driving activities at the NDD intake locations would adversely affect a few juvenile winter-run, spring-run, and fall-run Chinook salmon, steelhead, and green sturgeon.

2.5.1.1.3.1.2 Clifton Court Forebay

2.5.1.1.3.1.2.1 Species Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook salmon into CCF during construction activities, there is the potential for adverse effects of resuspended contaminants to fish present during pile driving. With implementation of the AMMs and in-water work window (July 1 through November 30), however, the in-water construction activities would mostly result in temporary, localized increases in turbidity and suspended sediment, which is not likely to adversely affect fish.

Extending in-water construction activities into November results in potential exposure of juvenile spring-run Chinook salmon (yearling smolts) and winter-run Chinook salmon (young-of-the year). San Joaquin River-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations. Less than one percent of fall-run Chinook salmon juveniles would be expected to be present during the work window.

Juvenile steelhead from both the Sacramento River basin via an open DCC gate and those emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries during the proposed in-water work window may be present in CCF during pile driving. Less than one percent of the annual juvenile emigration is expected to occur in the vicinity of the CCF during pile driving, however, because the majority of juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities.

Adult steelhead may potentially be found within the Delta during any month of the year. Typically adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Steelhead entering the San Joaquin River basin are believed to have a later spawning run, where adults enter the system starting in late October through December, indicating presence in the Delta a few weeks earlier. The timing of adult steelhead migration may potentially expose fish destined for either the Sacramento River basin or the San Joaquin River basin to contaminants resuspended by pile driving. Green sturgeon juveniles and sub-adults are also thought to be present in the southern Delta at any time of the year, potentially exposing those life stages to resuspended contaminants. The effects on adult and juvenile fish would likely be limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.1.3 Head of Old River Gate

2.5.1.1.3.1.3.1 Species Exposure and Risk

Contaminants released from resuspended sediment during pile driving at the HOR Gate are not expected to impact juvenile winter-run Chinook salmon, juvenile spring-run Chinook salmon, juvenile fall-run Chinook salmon, or juvenile steelhead, but may have a sublethal effect on exposed green sturgeon and those adult fall-run Chinook salmon and steelhead migrating to or from the San Joaquin River basin.

Construction activities at the HOR Gate will be limited to the in-water work window of August 1 through October 31, which will limit the potential for exposure to contaminants resuspended by pile-driving activities. Winter-run Chinook salmon, adult spring-run Chinook salmon, and juvenile fall-run Chinook salmon, and steelhead are not expected to be present during the in-water work window. NMFS assumes that potential San Joaquin River-basin spring-run Chinook salmon would exhibit similar emigration patterns to the Sacramento River basin populations, and, therefore, yearling smolt spring-run Chinook salmon may be present in the vicinity of the HOR gate in October, though likely in very few numbers. Adult steelhead may potentially be found within the Delta during any month of the year. Adult steelhead typically will enter the Delta during mid to late summer. Those fish will then enter the San Joaquin River basin system starting in late October through December. Timing of adult steelhead migration may potentially expose fish destined for the San Joaquin River basin to the physical impacts of pile driving.

Green sturgeon juveniles and sub-adults are also thought to be present in the southern Delta at any time of the year, potentially exposing those life stages to contaminants resuspended by pile driving at the HOR Gate. Impacts caused by pile driving operations are minimized by the relatively small area of effect. NMFS expects, however, that the effects will adversely affect some adult steelhead and juvenile and sub-adult green sturgeon, though likely limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.1.4 Barge Landing Locations

2.5.1.1.3.1.4.1 Species Exposure and Risk

Exposure to contaminants resuspended by pile driving during construction of barge landing locations is not expected to occur for juvenile spring-run Chinook salmon, juvenile and adult fall-run Chinook salmon, and juvenile steelhead, but may have a sublethal effect on exposed winter-run Chinook salmon, adult steelhead, and green sturgeon.

There will be approximately seven barge landing locations throughout the Delta. Construction at those locations will be limited to the in-water work window of August 1 through October 31, which will limit the potential for exposure to the activity.

At the barge landing locations, juvenile spring-run Chinook salmon and juvenile steelhead are not expected to be present during the in-water work window because it falls outside their migration period. In October it is expected that about two percent of juvenile winter-run-sized Chinook salmon will have begun migrating through the Delta and may be present in the vicinity of the Snodgrass Slough barge landing location. Also adult steelhead may potentially be found within the Delta during any month of the year. Typically, adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, and enter the Sacramento River system from July to early September. Steelhead entering the San Joaquin River basin enter the system starting in late October through December.

Timing of adult fall-run Chinook salmon and steelhead migrations has the potential to expose fish heading to either the Sacramento River basin or the San Joaquin River basin to contaminants resuspended by pile driving. Green sturgeon juveniles and sub-adults are also thought to be present in the Delta at any time of the year, potentially exposing that species to pile-driving-induced contaminants released from sediment at the barge landing locations. Exposure to contaminants resuspended by pile driving operations will be minimized by the relatively small area of effect.

NMFS expects that the activity will adversely affect a small number of winter-run Chinook salmon, adult fall-run Chinook salmon, adult steelhead and green sturgeon, though likely limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.2 Barge Traffic

Barge operations, routes, and assumptions are described in section *2.5.1.1.1.2 Barge Traffic*. The locations of barge landings are described in *section 2.5.1.1.1.1.4 Barge Landing Locations*.

The potential for large vessel operation to cause sediment disturbance and resuspension is described section *2.5.1.1.2.1.3.1 Species Exposure and Risk*.

Within the context of the proposed action, sediment disturbance because of barge operations will occur over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta) and over an extended period of time (up to approximately six years). For some routes, barges will travel nearly 100 miles from San Francisco to the Port of Stockton and other barge landing locations.

While most of the route will be in open water with fairly deep dredged channels (e.g., shipping channels), barge landing locations in the Delta will require vessels to maneuver in confined, shallow waterways. It is expected that the passage of the barges and tugs coupled with the effects of the propeller jet during normal operations and docking could resuspend a significant amount of sediment material each year. Resuspension of material will occur during each passage of a vessel and barge. The potential for barge traffic to liberate and mobilize previously buried legacy contaminants is greatest in the confined channels of the Delta. Resuspension of sediments provides a mechanism to reintroduce toxic compounds into the current environment and spread them throughout a much larger area due to river and tidal flows. This will expose any fish present to any contaminated sediment existing in those waterways through resuspension.

Likewise, the benthic community, including any prey species for the listed fish species, will be exposed to a chronic source of potentially contaminated sediment, which can lead to enhanced bioaccumulation of the contaminant at higher levels of the food chain. It is anticipated that the entire food chain may exhibit the effects of exposure to contaminated sediments during resuspension ranging from sublethal to lethal responses.

2.5.1.1.3.2.1.1 Winter-run Exposure and Risk

Detailed timing and spatial occurrence of winter-run Chinook salmon presence has previously been described in section *2.5.1.1.1.1 Pile Driving* and is summarized for this location and action in section *2.5.1.1.2.2.1.1 Winter-run Exposure and Risk*.

Barge traffic throughout the Delta and San Francisco estuary has the potential to expose the entire population of winter-run Chinook salmon to the resuspended sediments, which may include toxic compounds that can lower reproductive success. Barge traffic will overlap with migrations of juvenile and adult winter-run Chinook salmon throughout the five to six years of the projected construction schedule. The risk of winter-run Chinook salmon exposure is reduced compared to other species because only one proposed barge landing is located in the north Delta along the main winter-run Chinook salmon migration route. From Chipps Island to the Golden Gate, however, both migrations of juvenile and adult life stages of winter-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco.

The potential for increased contaminant exposure because of increased barge traffic will act as a stressor on winter-run Chinook salmon. Both adult and smolting juvenile winter-run Chinook salmon will be exposed to this stressor because of the spatial and temporal overlap of the increased barge traffic with winter-run migration. NMFS expects that the contaminant exposure effects of barge traffic will adversely affect some individual Sacramento River winter-run Chinook salmon though likely limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.2.1.2 Spring-run Exposure and Risk

Detailed timing and spatial occurrence of spring-run Chinook salmon presence have previously been described in section *2.5.1.1.1.1 Pile Driving*.

The high volume of construction-related barge traffic passing throughout the Delta and San Francisco estuary will potentially expose the entire CV spring-run Chinook salmon ESU to resuspended sediments that may include toxic compounds.

The potential for increased contaminant exposure because of construction-related barge traffic will act as a stressor on spring-run Chinook salmon. NMFS expects that the contaminant exposure effects of barge traffic will adversely affect some spring-run Chinook salmon, though likely limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants, as described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.2.1.3 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of juvenile and adult CCV steelhead presence has previously been described in section *2.5.1.1.1.1 Pile Driving* and is summarized for this location and action in section *2.5.1.1.2.2.1.3 Steelhead Exposure and Risk*.

Because the barge traffic occurs year round for the duration of the construction period, all emigrations of juvenile CCV steelhead and upstream and downstream migrations of adult CCV will overlap with the projected barge traffic operations during the five to six years of the projected construction schedule. The multiple barge landing locations are in the north Delta, central Delta, and south Delta, and thus occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of CCV steelhead overlap with projected routes of the barge traffic from San Francisco.

The potential for increased contaminant exposure due to increased barge traffic will act as a stressor on steelhead. NMFS expects that the contaminant exposure effects of barge traffic will adversely affect some individual CCV steelhead throughout the Delta, though likely limited to harassment of individuals that encounter turbidity plumes, or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.2.1.4 Green Sturgeon Exposure and Risk

The timing and spatial occurrence of sDPS green sturgeon presence has been generally described in section *2.5.1.1.1.1 Pile Driving* and characterized in further detail with specific regard to the exposure of green sturgeon to stressors emanating from year round barge traffic throughout the action area in sections *2.5.1.1.1.2.1.4 Green Sturgeon Exposure and Risk* and *2.5.1.1.2.2.1.4 Green Sturgeon Exposure and Risk*.

Because of the frequency and extent of planned barge operations in conjunction with the PA, all rearing juvenile sDPS green sturgeon and the annual migration of all spawning adult sDPS green sturgeon, will potentially be exposed to increased concentrations of contaminants released into the aquatic environment and the food chain.

The degree to which any individual fish may be adversely effected by the increased exposure to contaminants resuspended by the movement of barges throughout the action area is difficult if not impossible to ascertain with any precision. Because of the frequency and duration of the expected exposure, however, and the probability of bioaccumulation through normal rearing and feeding behavior throughout the waters of the Delta, NMFS expects that a high proportion of spawning adult and rearing juvenile sDPS green sturgeon will be adversely affected by increased exposure to contaminants resuspended and released into the aquatic environment by way of continuous barge traffic moving throughout the action area for the duration of the construction period. Adverse effects are likely limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants as described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.2.1.5 Fall/Late fall-run Exposure and Risk

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run Chinook salmon enter the San Francisco Bay in June and immigrate through the north Delta from July through December (Vogel and Marine 1991), with a peak in October. Juvenile late fall-run Chinook salmon are present in the Delta from July through January. Adult late fall-run Chinook salmon emigrate through the Delta from October through March (Vogel and Marine 1991).

The potential for toxic compounds to become resuspended with disturbed sediment will increase due to barge traffic, providing an additional stressor to fall and late fall-run Chinook salmon. Because barges will be operating year-round in locations that all Central Valley fall and late fall-run Chinook salmon adults and juveniles must pass through, the entirety of both adult and juvenile life stages may be exposed to increased contaminant concentrations caused by the PA barge traffic for the five- to six-year construction period.

A higher level of exposure is anticipated for fall-run Chinook salmon originating in the San Joaquin River basin because most barge traffic will use the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF.

NMFS expects that the contaminant exposure effects of barge traffic will adversely affect some fall-run Chinook salmon throughout the Delta, though likely limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.3 Geotechnical Analysis

Activities related to the geotechnical analysis proposed in and required for the PA are described in section *2.5.1.1.2.3 Geotechnical Analysis*.

Activities associated with geotechnical analysis can increase exposure to contaminants by multiple pathways. Sediments disturbed by the activities can potentially resuspend contaminated sediments that had been latent in settled sediments. The closed circulating system employed in the rotary drilling method and sampling protocols described in section *2.5.1.1.2.3 Geotechnical Analysis*, however, will reduce the likelihood that any contaminants potentially present in the soil horizons below the channel bottom would be introduced into the aquatic environment as a result of these operations. Also, during these activities, contaminants may be introduced to the aquatic environment from accidental spills of oil, gas, or hydraulic fluids associated with operating a barge or boat during overwater geotechnical investigations. Implementation of the following AMMs is expected to minimize the potential for introduction of contaminants to surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials.

- AMM1 Worker Awareness Training
- AMM2 Construction Best Management Practices and Monitoring
- AMM3 Stormwater Pollution Prevention Plan
- AMM4 Erosion and Sediment Control Plan
- AMM14 Hazardous Material Management
- AMM5 Spill Prevention, Containment, and Countermeasure Plan

- AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material
- AMM7 Barge Operations Plan
- HMMP Hazardous Materials Management Plan

2.5.1.1.3.3.1 Species Exposure and Risk

As described in section *2.5.1.1.2.3 Geotechnical Analysis*, during construction of the NDD, CCF, HOR, and barge landings, small numbers of fish (juvenile winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead) are expected to occur at these locations during the margins of the in-water work windows, which may cause those individuals to be exposed to contaminants that are exposed or introduced during geotechnical exploration.

While there is potential for contaminants to be introduced to the aquatic environment from either the borings themselves or accidental spills of oil, gas, or hydraulic fluids, several measures—including AMMs, the closed circulating system of the rotary drilling method, and sampling protocols—make it highly unlikely that any contaminants potentially present in the soil horizons below the channel bottom would be introduced into the aquatic environment as a result of geotechnical analysis operations.

NMFS therefore expects that the contaminant exposure effects of geotechnical analysis will adversely affect a few juvenile steelhead and winter-, spring-, and fall-run Chinook salmon and a few adult winter- and spring-run Chinook salmon and sturgeon. NMFS expects that the effect will adversely affect some steelhead and fall-run Chinook salmon adults and some juvenile green sturgeon. Adverse effects would likely be limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4 Dredging

As noted in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*, the proposed action includes dredging activities within the project construction area that can cause sediment disturbance.

Section *2.5.1.1.3 Contaminant Exposure* indicates that disturbed sediment can mobilize and redistribute contaminants that were previously latent, exposing listed fish species. Measured sediment plumes from hydraulic dredging operations (Hayes et al. 2000) suggest that less than 0.1 percent of disturbed sediments and associated contaminants would likely be re-suspended during cutterhead dredging operations. Using a suction dredge in particular is expected to minimize to the point of insignificance any dispersion of resuspended contaminants released through the dredging process. Also, the potential release of contaminants from suspended sediment is expected to be limited because many of the chemical constituents preferentially adsorb or attach to organically enriched or fine particles of sediment. These heavier sediments are also expected to resettle to the bottom relatively quickly. Additionally, using a suction dredger will keep much of the re-suspended sediment and turbidity plume contained.

Implementation of BMPs and the following AMMs are expected to minimize the potential for introduction of contaminants to surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials:

- *AMM2 Construction Best Management Practices and Monitoring;*
- *AMM4 Erosion and Sediment Control Plan;*
- *AMM5-Spill Prevention, Containment, and Countermeasure Plan;*
- *AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material.*
- *HMMP Hazardous Materials Management Plan*

2.5.1.1.3.4.1 North Delta Diversion Intake Locations

Dredging activities associated with construction of the north Delta intakes and the potential for sediment disturbance at the NDD intake locations are described in section *2.5.1.1.2.4.1 North Delta Intake Locations*.

Not only can such disturbance potentially increase localized turbidity levels, but sediment resuspension can also expose latent contaminants. Proposed intake sites are downstream of the City of Sacramento where sediments have been affected by historical and current urban discharges from the city. No information on sediment contaminants at these sites is currently available.

It is assumed that after construction at the NDD intake locations is complete, the area in front of each intake will need to be dredged to provide appropriate flow conditions at the intake entrance. Current estimates indicate that total dredging and channel disturbance would affect 12.1 acres of dredging outside the cofferdams. If required, dredging will occur during the in-water work window of June 1through October 31.

2.5.1.1.3.4.1.1 Chinook Salmon Exposure and Risk

The timing of the Chinook salmon presence has been described in section *2.5.1.1.1 Acoustic Stress*.

Limiting construction-related dredging activities at the NDD intake locations to the June 1 through October 31 work window is expected to minimize exposure to Chinook salmon species because:

- Juvenile winter-run Chinook salmon are expected to be present in the Delta from October to April, while adult winter-run are present in the Delta between November and June.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May, with adult spring-run presence between January and June.
- Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August. Adults are present from July to December.
- Juvenile late fall-run Chinook salmon are expected to be present from July through September. Adult late fall-run Chinook salmon are expected to be present in the Delta from November through April.

Given the timing and location of in-water construction activities and that in some years a small proportion of the population may be migrating through the action area, NMFS expects any juvenile winter- and spring-run and adult winter-run Chinook salmon, some juvenile and adult fall-run Chinook salmon, and some juvenile late-fall run Chinook salmon present would be exposed to contaminants resuspended during construction-related dredging. Any adverse effects are expected to be limited to harassment of individuals that encounter turbidity plumes, however, or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.1.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the NDD location has been described in section *2.5.1.1.1 Acoustic Stress*.

The in-water water work window overlaps with a substantial proportion of the adult upstream migration because adult steelhead start to enter the Delta region as early as June and peak presence is in September. Small numbers of adult CCV steelhead may continue to emigrate upriver through March.

Data from northern and central Delta fish monitoring programs, indicate that steelhead smolts begin to enter the northern Delta as early as September through December, but do not substantially increase in numbers until February and March. It is estimated that less than one percent of the annual juvenile steelhead population will pass during September and October.

Because construction-related dredging activities will occur during the adult steelhead upstream migration period, NMFS expects that the increased contaminant exposure caused by dredging will adversely affect some adult steelhead. Because most of the juvenile steelhead emigration occurs after the end of the dredging period, NMFS expects that increased contaminant exposure will adversely affect a few juvenile steelhead. Any adverse effects are expected to be limited to harassment of individuals that encounter turbidity plumes, however, or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.1.3 Green Sturgeon Exposure and Risk

Timing of green sturgeon presence has been described in section *2.5.1.1.1Acoustic Stress*.

The in-water work window of June 1 through October 31 will avoid the peak upstream migration period of spawning adult green sturgeon (late February to early May), although both post-spawn adults and rearing juveniles may potentially be present in the vicinity of the north Delta near the proposed intake structures on the Sacramento River during any month of the year. Juvenile and post-spawn adult sDPS green sturgeon could therefore be present at the NDD location during the in-water work window and subject to exposure to any contaminants released to the aquatic environment by way of dredging throughout the construction period.

NMFS expects a few post-spawn adults and juvenile sDPS green sturgeon migrating or rearing in the Sacramento River during dredging activities to be exposed to slightly higher concentrations of contaminants. But because most of the contaminants released through dredging will be removed with the dredged material or otherwise contained, adverse effects will likely be limited to the types of behavioral effects associated with increased turbidity and sediment or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.2 Clifton Court Forebay

Dredging activities associated with the construction at CCF and the potential for sediment disturbance are described in section *2.5.1.1.2.4.2 Clifton Court Forebay*.

Not only can such disturbance potentially increase localized turbidity levels, but sediment resuspension can also expose latent contaminants.

To minimize adverse effects of sediments releasing contaminants, dredged material will likely require disposal. Any sediments found to be suitable for use in constructing the new embankments within the modified CCF will be stockpiled within the construction area limits and reused. Unsuitable material will be disposed as described in *AMM 6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material.*

Recognizing that design of these modifications is still in an early stage, DWR, Reclamation, NMFS, CDFW, and USFWS have agreed to ongoing collaborative efforts to ensure that final design and construction procedures for CCF minimize adverse effects to listed species to the extent practicable. Accordingly, representatives from each agency will participate in a Clifton Court Forebay Technical Team.

2.5.1.1.3.4.2.1 Chinook Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook into CCF during construction activities, there is the potential for adverse effects of resuspended contaminants to fish present during the dredging component.

Extending in-water construction activities into November results in potential exposure of juvenile spring-run Chinook salmon (yearling smolts) and winter-run Chinook salmon (young-of-the year). San Joaquin River-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations. Less than one percent of fall-run Chinook salmon juveniles would be expected to be present during the work window. Although there is some potential for exposure to contaminants, the effects on adult and juvenile fish would likely be limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.2.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the Clifton Court location has been described in section *2.5.1.1.1 Acoustic Stress*.

It is expected that this water body will be accessible to both CCV steelhead juveniles from the Sacramento River basin via an open DCC gate and to fish emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries during the proposed in-water work window. The likelihood of fish from the Sacramento River being present, however, diminishes with distance from the main stem of the San Joaquin River.

Less than one percent of the annual juvenile emigration is expected to occur at the CCF during the proposed work window (July 1 through November 30). The majority of juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities. It is expected that the timing of adult presence at the CCF location will be later than that observed for the North Delta because of its southern Delta location and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through November with the proposed in-water work window.

Because dredging of CCF will occur only during the in-water work window (July 1 through November 30), it is expected that adult steelhead will be the predominant life stage affected by dredging in CCF due to the overlap in the dredging work window and the upstream migration of adult steelhead. Few juvenile CCV steelhead are expected to be affected by the dredging actions in CCF due to their later migration period.

Because most juvenile steelhead emigration occurs after the end of the dredging action, NMFS expects that the contaminant exposure effects of dredging at the CCF will adversely affect a few juvenile steelhead. Adult steelhead migration timing overlaps with the work window at CCF, especially given the extension to November for in-water work. Therefore, NMFS expects that the sediment effects of dredging at the CCF will adversely affect some adult steelhead. The effects on adult and juvenile fish would likely be limited to harassment of individuals that encounter turbidity plumes or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.2.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk*.

Although there is some uncertainty and variability associated with Delta residence time by life stage, spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. Historical salvage records of green sturgeon at the Skinner and Tracy salvage facilities indicate a general peak in the summer months, although very few sturgeon have been encountered there in recent years (National Marine Fisheries Service 2015a).

Adherence to the July 1 through November 30 in-water construction period will avoid the peak upstream migration period of adult green sturgeon transiting the action area (late February to early May) to upstream spawning habitats. Post-spawning adults, sub-adults, and juveniles may be present in the Delta during the late summer and fall months, however, and could therefore become exposed to increasing concentrations of contaminants released by dredging operations conducted in the CCF during the in-water construction period. A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta.

NMFS expects a small portion of post-spawn adults and juvenile sDPS green sturgeon migrating or rearing in the vicinity of CCF to be exposed to potential contaminants released from disturbed sediment during dredging activities conducted at the CCF. Adverse effects are likely limited to behavioral modifications, from the mobilized sediment, or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.3 HOR Gate

Dredging at HOR gate during construction is likely to result in mobilized redistribution of contaminants settled into the sediment, which may potentially adversely affect listed fish.

Dredging to prepare the channel for construction of the HOR gate will occur along 500 feet of channel, from150 feet upstream to 350 feet downstream of the proposed gate location. A total of up to 1,500 cubic yards of material is expected to be dredged. Dredging will last approximately 15 days and will be performed within the August 1 through October 31 in-water work window for this location. Sediment mobilization may redistribute bound contaminants into Old River and the San Joaquin River downstream of the activity, and therefore any fish present may be exposed.

As described in sections *2.5.1.1.2.4.1 North Delta Intake Locations* and *2.5.1.1.3.4.1 North Delta Diversion Intake Locations*, implementation of the appropriate BMPs and AMMs is proposed to minimize potential adverse effects on fish due to dredging.

2.5.1.1.3.4.3.1 Winter-run Exposure and Risk

The timing and spatial occurrence of juvenile and adult winter-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving*.

Juveniles are present in the Delta from October through April, while adults are present in the Delta from November through June. Because the HOR gate is on a distributary of the San Joaquin River far from the main winter-run Chinook salmon migration corridor (i.e., the Sacramento River), it is highly unlikely that winter-run Chinook salmon would be found in the vicinity of the gate. Also, the in-water work window for the HOR gate is August 1 through October 31, so the potential for dredging-induced release of contaminants is not expected to coincide with winter-run Chinook salmon presence. Given the timing and location of winter-run Chinook salmon presence and migration compared to the proposed in-water work window, NMFS expects that the potential for contaminant release from construction dredging at the HOR gate would not adversely affect winter-run Chinook salmon.

2.5.1.1.3.4.3.2 Spring-run Exposure and Risk

The timing and spatial occurrence of juvenile and adult spring-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving*.

Both San Joaquin River basin spring-run Chinook salmon adults and any straying adults from the Sacramento River basin will most likely already be staging for spawning in upriver locations by August and are not expected to be migrating through the activity area during the August 1 through October 31 work window. Although there is some uncertainty due to lack of monitoring data regarding the timing of outmigrating juvenile spring-run Chinook salmon in the San Joaquin River basin, NMFS assumes that these fish exhibit similar emigration patterns to the Sacramento River basin populations, and, therefore, yearling smolt spring-run Chinook salmon may be present in the vicinity of the HOR gate in October, though likely in very few numbers. NMFS therefore expects that any contaminants released in the resuspension of sediment and turbidity from construction-related dredging at the HOR gate will adversely affect a few individual spring-run Chinook salmon. Adverse effects are likely limited to behavioral modifications, from the mobilized sediment, which could result in increased risk of predation (as described in section *2.5.1.1.6 Increased Predation Risk*) or sublethal effects of released contaminants (described above in section *2.5.1.1.3Contaminant Exposure*).

2.5.1.1.3.4.3.3 Steelhead Exposure and Risk

The timing of CCV steelhead at the HOR gate location has been described in section *2.5.1.1.1 Acoustic Stress*.

In summary, juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Because dredging associated with constructing the HOR gate occurs from August 1 through October 31, and is expected to be completed over a two-year period, only a minimal amount of temporal overlap with the presence of juvenile CCV steelhead is expected.

Based on regional monitoring data and salvage data from the SWP and CVP fish collection facilities, less than one to two percent of the annual juvenile emigration from either basin is expected to occur during the proposed work windows. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location, but their numbers appear to be considerably lower than those fish originating in the Sacramento River basin. It is not expected that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate, even though juvenile CCV steelhead from this basin are present at the CVP and SWP salvage facilities.

Adult CCV steelhead from the Sacramento River basin begin to migrate upriver from the Delta in June, with increasing numbers of fish arriving from August through September, before tapering off in October and November. Peak migration (approximately 69 percent of annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January, therefore a small proportion may be exposed to dredging activities. Because most juvenile steelhead emigration occurs after the end of the dredging action, a few juvenile steelhead will potentially be exposed to resuspended contaminants, resulting in adverse effects. Adverse effects are likely limited to behavioral modifications, from the mobilized sediment, or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.3.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Although there is some uncertainty and variability associated with Delta residence time by life stage, juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta during every month of the year, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta. Because of the widespread and year-round presence of juvenile and sub-adult sDPS green sturgeon in the waters of the Delta, these life stages could be present in the vicinity of the HOR gate and could be exposed to resuspended contaminants in the water column during dredging operations conducted during the August 1 through October 31 in-water construction period.

As described in section *2.5.1.1.3 Contaminant Exposure*, green sturgeon are expected to be more vulnerable than salmonids to the negative effects of contaminants released during dredging activities because of their benthic-oriented behavior, which conceivably put them in closer proximity to the contaminated sediment horizon. Adverse effects could include physical injury, or physiological effects due to bioaccumulation of contaminated prey.

Given the likely presence of juvenile and sub-adult life stages of green sturgeon at the HOR gate location during the work window, NMFS expects that contaminants released during dredging at the HOR gate site would potentially expose a large proportion of juvenile and sub-adult green sturgeon. Adverse effects are likely limited to behavioral modifications, from the mobilized sediment, or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*. Uncertainty as to which contaminants would be released, however, and at what levels, creates uncertainty as to the level of effect associated with this activity. Conducting geotechnical investigations before construction of the HOR gate, and monitoring as per the HMMP, is expected to provide up-to-date and site-specific contaminant profile information.

2.5.1.1.3.4.3.5 Fall/Late Fall-run Exposure and Risk

Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult fall-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving*.

Juvenile fall-run Chinook salmon do not occur in the Delta during the August through October construction window and are not likely to be exposed to contaminants released during construction-related dredging at the HOR gate location and are, therefore, unlikely to be adversely affected.

Adult fall-run Chinook salmon from the San Joaquin basin, or strays from the Sacramento River basin, will be immigrating to their natal spawning grounds from September through December. Given that the HOR gate construction site will be adjacent to the San Joaquin River, some immigrating adults will likely be in the construction area during the August through October construction period. Fall-run Chinook salmon adults are likely to be exposed to any increases of contaminants in the resuspended sediment because of PA dredging at the HOR gate.

Although there is temporal and spatial overlap between fall-run Chinook salmon adults and the short-term duration of dredging activities, NMFS expects that any adverse effects from contaminants released into the water column during dredging at HOR gate would likely be limited to behavioral modifications from the mobilized sediment or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

Late Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult late fall-run Chinook salmon has been described in section *2.5.1.1.1.1 Pile Driving*.

Late fall-run Chinook salmon occur in the Sacramento River basin, but are not currently known to occur in the San Joaquin River basin. While late fall-run Chinook salmon adult strays from the

Sacramento River basin occur occasionally in the San Joaquin River near the HOR gate location, the likelihood of occurrence is low. Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the August through October construction window at HOR gate. Any juveniles that move into the Old River may be adversely affected by any releases of contaminants due to dredging activities at the HOR gate, but numbers are likely very low. Any adverse effects would likely be limited to behavioral modification, from the mobilized sediment or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.4 Barge Routes and Landings

As discussed previously in section *2.5.1.1.2.4.4 Barge Routes and Landings*, dredging associated with barge operations can be expected during the construction activity period of the proposed action.

Barge landings are distributed over a broad area of the Sacramento-San Joaquin Delta and thus will have a wide source of sediment and contaminant inputs. These will range from natural background sources based on local geology to inputs from agricultural sources or heavy industrialized port operations.

Sacramento-San Joaquin Delta barge routes will cover nearly 100 miles of waterways from San Francisco to the Port of Stockton and landing locations at the NDD intake location and CCF. While barge landings are in operation, it is assumed that precautionary spot dredging will occur to provide safe passage through the proposed routes to the barge landing sites and that these sites will be maintained to provide safe operating depths for barges and tug boats.

NMFS also assumes that the in-water work window for dredging activities associated with barge operations will be the same as that used for construction at the barge landings (August 1 through October 31). This work window is expected to minimize dredging exposure to fish. Furthermore, NMFS assumes that the suite of AMMs proposed for minimizing dredging impacts will be beneficial in reducing the exposure to dredging-related contaminant resuspension.

NMFS believes that the level of potential contaminants is related to the frequency of dredging operations in the location of future barge landing sites, as well as the nature of flushing flows found at those sites. In areas such as the NDD intake sites, strong riverine flows will flush most fine sediment and organic materials away from the site, leaving heavier mineral substrates such as sand. These larger sized particulate, mineral-based substrates have less propensity to sequester contaminants, particularly organic compounds, because they have less surface-area-to-volume ratios than finer sized materials such as silt and clays.

Conversely, in areas such as the central and south Delta barge landing locations, as well as Snodgrass Slough, where flushing flows are not as strong and sediment has accumulated along the banks, there is more potential for contaminants to have been sequestered in the sediment over time. These sediment deposits are typically comprised of fine-sized particulate matter such as silt, clays, or decayed organic matter. These sediments tend to have higher organic carbon levels than those areas where sand is the predominant sediment constituent and have much greater surface-area-to-volume ratios to which contaminants can undergo sorption to the surface of the sediment particle (Rand 1995). These areas often require frequent dredging due to accumulation of sediments as a result of quiescent hydraulics conditions. Such areas are at greater risk of contaminant deposition.

2.5.1.1.3.4.4.1 Chinook Salmon Exposure and Risk

Detailed timing and spatial occurrence of winter-run, spring-run, and fall/late fall-run Chinook salmon presence in the Delta has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Limiting dredging activities of the PA within the Delta to the August 1 through October 31 work window is expected to minimize exposure to Chinook salmon, because:

- Winter-run Chinook salmon juveniles are present in the Delta from October through April, with about two percent of a year's juveniles found in the north Delta in October (DJFMP). Adult winter-run Chinook salmon are present in the Delta from November through June, and, therefore, are not expected to be adversely affected.
- Spring-run Chinook salmon juveniles may be present in the north Delta from November to June. Adult spring-run Chinook salmon are present in the Delta from January to March as they begin to migrate upstream into the Sacramento River or San Joaquin River basin. Therefore spring-run Chinook salmon are not expected to be adversely affected during dredging activities.
- Juvenile fall-run Chinook salmon do not occur in the Delta during the August through October construction window. Therefore, this life stage is not expected to be exposed to dredging activities at barge landing locations and barge routes. The fall-run Chinook salmon adult immigration period for both the San Joaquin River basin (September through December) and the Sacramento River basin (July through December) overlap with the August through October dredging period. A higher level of exposure is anticipated for fall-run Chinook salmon originating in the San Joaquin River basin because most barge routes will occur in the Stockton Deep Water Ship Channel and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF.
- Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the August through October in-water work window for dredging. Juveniles are therefore likely to be exposed to dredging activities at barge landing locations and barge routes. The timing of adult immigration of late fall-run Chinook salmon (end of October through beginning of April) only slightly overlaps with the window for dredging at barge landings and routes.

NMFS therefore expects that exposures to contaminated sediments associated with dredging at barge landings and barge access routes are likely to occur for a small proportion of winter-run Chinook salmon juveniles, a large proportion of fall-run Chinook salmon adults, a large proportion of late fall-run Chinook salmon juveniles, and a small proportion of late fall-run Chinook salmon adults. Adverse effects are likely limited to behavioral modifications from the mobilized sediment or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

2.5.1.1.3.4.4.2 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of CCV steelhead presence in the Delta has previously been described in section *2.5.1.1.1.1 Pile Driving*.

The in-water water work window of August 1 through October 31 overlaps with a substantial proportion of the adult CCV steelhead upstream migration in the Sacramento River. As previously described for pile driving, adult steelhead start to enter the Delta region as early as June (0.2 percent of annual total based on catch per 100 trap hours) increasing to 12.1 percent in August, 44.5 percent in September, 24.6 percent in October, and 6.8 percent in November. Low levels of adult CCV steelhead continue immigration upriver through March. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January.

Data from the northern and central Delta fish monitoring programs indicate that steelhead smolts begin to enter the northern Delta from the Sacramento River as early as September through December, but do not substantially increase in numbers until February and March. It is estimated that less than one percent of the annual juvenile steelhead population will pass through the Delta during September and October. The downstream migration of San Joaquin River basin steelhead smolts into the Delta peaks in April and May.

NMFS expects that a high proportion of juvenile and adult CCV steelhead would be exposed to dredging activities. Although exposure is likely, adverse effects are likely limited to behavioral modifications from the mobilized sediment or sublethal effects of released contaminants described above in section *2.5.1.1.3 Contaminant Exposure*.

Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in section *2.5.1.1.1.1 Pile Driving*.

Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. Therefore NMFS expects these life stages to be broadly exposed to any contaminants released from resuspended sediment during dredging operations (August 1 to October 31) associated with the barge landings and barge routes.

As described in section *2.5.1.1.3 Contaminant Exposure*, green sturgeon are expected to be more vulnerable than salmonids to the negative effects of contaminants released during dredging activities because of their benthic-oriented behavior, which conceivably put them in closer proximity to the contaminated sediment horizon. Adverse effects are likely limited to behavioral modifications, from the mobilized sediment or sublethal effects of released contaminants, but may also result in physical injury or physiological effects due to bioaccumulation of contaminated prey. Uncertainty as to which contaminants would be released, and at what levels, creates uncertainty of the level of effect that might be associated with this exposure. Conducting geotechnical investigations at the barge landing locations and along routes is expected to provide up-to-date, site-specific contaminant profile information.

2.5.1.1.4 Increased Temperature

Water temperatures can be affected by a number of factors, including air temperatures, elevation, flow and velocity, and presence of riparian vegetation. Loss of riparian vegetation is likely to occur during clearing and grubbing activities at construction sites, including the NDD intake sites, barge landings, CCF, and HOR. It may also occur as an indirect effect of creating temporary access points to the river for construction.

Riparian vegetation, specifically shaded riverine aquatic (SRA) habitat, provides overhead cover, which results in shade and protection, increases large woody material recruitment, provides slower flow velocities for resting spots, and provides substrate for food production (such as aquatic and terrestrial invertebrates) for anadromous fish (Anderson and Sedell 1979, Pusey and Arthington 2003).

A vibrant riparian corridor provides important water temperature cooling, especially in smaller streams. The loss of riparian vegetation can therefore increase predation rates (see section *2.5.1.1.6 Increased Predation Risk)* and reduce food production and feeding rates for juveniles (see section *2.5.1.1.5 Reduced Prey Availability*). Also, anadromous fish juveniles may be exposed to increased water temperatures when the riparian corridor has been degraded, which may result in decreased growth and survival (Michel 2010, Michel et al. 2012, USFWS 1992).

2.5.1.1.4.1 Clearing and Grubbing at Construction Sites

Because loss of riparian vegetation is likely to occur during clearing and grubbing activities at construction sites, including the NDD intake sites, barge landings, CCF, and HOR, adverse effects to species may occur. Decreased riparian vegetation may also occur as an indirect effect of creating temporary access points to the river for construction. Some locations of cleared or cut riparian vegetation will be replaced with angular rock or a structure or facility and, therefore, will result in permanent loss. Other locations may be left to recolonize once construction activity has been completed, which may take one to five growing seasons depending on best management measures taken.

Although construction of the proposed project is likely to reduce riparian vegetation in the footprint of each new facility, the Sacramento River and Delta are wider, faster moving migration corridors for Central Valley anadromous fish, which are less likely to experience warming of water temperatures due to limited decreases in riparian vegetation. Because any water temperature increases as a result of decreased riparian vegetation in these locations would be difficult to detect, fish species will likely not be adversely affected.

2.5.1.1.5 Reduced Prey Availability

One of the most important habitat attributes of the riverbed to listed anadromous fish species in the action area is the production of food resources for rearing and migrating juveniles, such as drifting and benthic invertebrates, forage fish, and fish eggs. Benthic invertebrates, such as oligochaetes and chironomids (dipterans), are the predominant juvenile salmonid and sDPS green sturgeon food items produced in the silty and sandy substrates of the action area. Although specific information on food resources for green sturgeon within freshwater riverine systems is lacking, they are presumed to be generalists and opportunists that feed on similar prey to other sturgeons (Israel and Klimley 2008), such as the population of white sturgeon present and coexisting with green sturgeon in the Sacramento basin. Seasonally abundant drifting and benthic invertebrates have been shown to be the major food items of white sturgeon in the lower Columbia River (Muir et al. 2000). As sturgeons grow, they begin to feed on oligochaetes, amphipods, smaller fish, and fish eggs as represented in the diets of white sturgeon (Muir et al. 2000).

Contaminants may impact food sources, which can result in bioaccumulation of contaminants from feeding on them, adversely affecting anadromous fish (see previous discussion in section

2.5.1.1.3 Contaminant Exposure). In this section, we discuss how disturbance of the riverbed is likely to occur during construction of the PA through pile-driving activities, barge traffic, geotechnical analysis, dredging, and clearing and grubbing, which has the potential to reduce prey availability for listed anadromous fish species in the action area. The activity resulting in the largest disturbance is through dredging, which has the potential to entrain and thereby remove populations of small demersal fish and benthic invertebrates from the channels within the action area, which represents a loss of the forage base to outmigrating juvenile salmonids and rearing green sturgeon.

The loss of benthic food resources, such as amphipods or isopods, could reduce fish growth rates and increase the energy expended searching for food, depending on the density of the animal assemblages on the channel bottom and the benthic invertebrate population recovery rate, which can be months to years (McCauley et al. 1976, Oliver et al. 1977, Currie & Parry 1996, Tuck et al.1998, Watling et al. 2001).

Impacts from loss of food resources within the action area are more likely to occur to green sturgeon, which are specialized benthic feeders, but also may affect juvenile salmon and steelhead. NMFS believes that small invertebrates—such as annelids, crustaceans (amphipods, isopods), and other benthic fauna—would be unable to escape the suction of a hydraulic dredge and be lost to the system. Also, many benthic invertebrates have pelagic, surface-oriented larvae. Therefore, the loss of these benthic invertebrates may reduce the abundance of localized zooplankton populations in the upper regions of the water column where juvenile salmonids migrate through the Delta.

The time needed to fully recolonize the disturbed channel bottom is unknown and further complicated by the variable frequency and timing of channel bottom disturbances, as well as the various reach locations where these disturbances are likely to occur. The variable cycles of channel bottom disturbances between June 1 and November 30 in any given year may preclude replacement of the forage base through recruitment from surrounding areas before the onset of the following winter and spring migration period of anadromous fishes through the action area (Nightingale and Simenstad 2001) and will likely pose a barrier to the re-establishment of a "natural climax" benthic invertebrate assemblage in any specific reach.

As these organisms occupy habitat types that are prone to disturbance under natural conditions, however, they would likely recolonize these areas fairly rapidly by drifting and crawling from adjacent non-disturbed areas (Mackay 1992; Nichols and Pamatmat 1988). There are no indications as to what the species richness or diversity of the recolonizing community might be within the action area, however, or the proportion of native to invasive species in the resulting community structure and the nutritional value of those prey resources to listed anadromous fish species.

Overall, reduced prey availability in the migration and rearing habitats of listed anadromous fishes may impact the viability of those populations by increasing stress and reducing the overall fitness of individuals migrating through or rearing in the Delta. Furthermore, nutritional deficiencies and reduced fitness of individuals may result in an abbreviated residence time in the waters of the Delta, stunted growth rates, and diminished resiliency for survival in the ocean, in addition to the potential for increased susceptibility to disease, contaminants, predation, entrainment, and other project-related effects that are likely to be compounded by exposure to multiple stressors during their residence in and migration through the action area.

2.5.1.1.5.1 Pile Driving

Pile driving has the potential to harm or harass salmonids and green sturgeon within the action area. The ways in which pile driving can affect species are through pile-driving-induced acoustic stress (see section *2.5.1.1.1 Acoustic Stress*), the resuspension of sediments and associated turbidity (see section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*), the exposure to contaminants previously sequestered in the benthos (see section *2.5.1.1.3 Contaminant Exposure*), and the increased exposure to potential predators (see section *2.5.1.1.6.1 Pile Driving*). The disturbance to the environment (benthos and water column) caused by pile driving may also impact fish through a reduction in the availability of prey species (described here in section *2.5.1.1.5.1 Pile Driving*).

Overall, there is little evidence to suggest that pile-driving activities will affect the availability of anadromous fish prey species in the short term. And while it has been shown that hydraulic pile driving used in dock construction has the potential to significantly alter the long-term sediment grain size composition, which may in turn affect epibenthic faunal assemblages, stomach content analysis of juvenile salmon caught in Puget Sound indicate that most fish continue to feed successfully near pile driving operations (Feist et al. 1996). Furthermore, the effect of pile driving on prey availability is expected to manifest in a way similar to that of other anthropogenic waves where chronic, long-term disturbance would be expected to have a negative impact (Bishop 2004), but short-term disturbances could have a beneficial effect of increasing prey availability (Gabel et al. 2011) through resuspension. Lastly, the potential extent of exposure is expected to be limited as observations and analyses of pile driving conducted in an environment similar to the Sacramento San Joaquin Delta indicate that very little sediment, resuspended by pile driving, is observable (Dave Evans and Associates 2012), meaning any potential impact to prey availability would be expected to be minimal as well.

2.5.1.1.5.1.1 Species Exposure and Risk

The spatial extent of listed species occurring contemporaneously with pile driving operations has been described previously (see section *2.5.1.1.1.1 Pile Driving*) and, for the most part, Chinook salmon are not expected to be present during pile driving operations. Species that have the potential to be present year round (for example, steelhead and green sturgeon) and small numbers of Chinook salmon found at either end of the in-water work window in some years could be present during pile driving operations. Given the extremely small spatial extent of effect, however, with regard to prey availability, NMFS expects that pile-driving operations will not adversely affect—and may even have a minor beneficial effect—on winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, CCV steelhead, and green sturgeon.

2.5.1.1.5.2 Barge Traffic

Vessel traffic and anthropogenic waves will act to resuspend infauna and detach invertebrates from hard surfaces and aquatic flora (Fleit et al. 2016), which have been shown to have a varying degree of effect on prey availability. Chronic disturbance caused by long-term exposure to anthropogenic waves will result in decreasing assemblages of macrobenthic infauna and altered community structure (Bishop 2004), which may result in decreased growth and survival of anadromous fish. Alternatively, the proximate effect, immediately post-disturbance, will be to increase prey accessibility and foraging success as benthic invertebrate prey species are exposed and resuspended in the water column (Gabel et al. 2011).

2.5.1.1.5.2.1 Species Exposure and Risk

The spatiotemporal extent of barge traffic is described in section *2.5.1.1.1.2 Barge Traffic*.

In summary, over the course of the five to six years of construction of the tunneled conveyance and other facilities, it is projected that up to 15,000 barge trips (30,000 one way) may be added to the daily vessel traffic over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta). Considering that this increase in barge traffic will be year-round, all salmonids are expected to be exposed to the increased vessel traffic and its effect on prey availability.

Because most of the barge traffic will be using the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the primary landing sites at Bouldin Island and the CCF, those species or runs originating in the Sacramento River basin will have a reduced exposure compared to those entering the Delta from the San Joaquin River.

That said, all species must pass through the western Delta and the waterways leading to the ocean where they will have some level of exposure to increased barge traffic through the Delta and San Francisco Estuary. With regard to prey availability, NMFS expects that barge traffic will not adversely affect—and may even have a short-term beneficial effect—on winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, and steelhead. Juvenile and spawning adult green sturgeon, however, may be adversely affected by a reduced prey base over the long term.

2.5.1.1.5.3 Geotechnical Analysis

Activities associated with the geotechnical analysis to be conducted as part of the PA are described in detail in section *2.5.1.1.2.3 Geotechnical Analysis*.

These activities include approximately 90 to 100 overwater geotechnical borings and cone penetration tests to be drilled in the Delta waterways during the designated in-water work window over several years. By their nature, these activities will disturb and remove a small portion of the river bed and, therefore, have the potential to effect the benthic infauna, including species common in the diet of salmonids and sturgeon. The extent and area of effect is expected to be extremely small, however, because the conductor casing of each boring will only be about 8 inches in diameter. Multiplied by the number of cores taken (90-100), the total area of sediment removal is expected to be at most 17.5 square feet. And although the drill operates by pumping fluid through the material to be removed, the effect to the surrounding environment will be minimal as the drilling fluid remains within the closed system of the conductor casing and recirculation tank.

2.5.1.1.5.3.1 Species Exposure and Risk

The spatial extent of listed species occurring contemporaneously with the geotechnical analysis has been described previously (see section *2.5.1.1.1.1 Pile Driving*) and, for the most part, Chinook salmon are not expected to be present during pile-driving operations. Species that have the potential to be present year round (for example, steelhead and green sturgeon) and small numbers of Chinook salmon found at either end of the in-water work window in some years could be present during the geotechnical analysis. Given the extremely small area of effect and the small likelihood of disturbance outside of the removal area, however, NMFS expects that there would not be an appreciable reduction in prey availability caused by the geotechnical analysis and that it will not have an adverse effect on winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, CCV steelhead, and green sturgeon.

2.5.1.1.5.4 Dredging

As noted in section *2.5.1.1.2 Sediment Concentration and Turbidity Stress*, the proposed action includes dredging activities within the project construction area that can cause sediment disturbance. Section *2.5.1.1.2.4 Dredging* describes the extent of the activity.

As noted in section *2.5.1.1.5 Reduced Prey Availability*, dredging may potentially reduce the benthic forage base to listed fish species. Reine and Clark (1998) estimated that the mean entrainment rate of a typical benthic invertebrate, represented by the grass shrimp, when the cutterhead of the dredge was positioned at or near the bottom, was 0.69 shrimp per cubic yard, but rose sharply to 3.4 shrimp per cubic yard when the cutterhead was raised above the substrate to clean the pipeline and cutterhead assembly. Likewise, benthic infauna, such as clams, would be entrained by a suction dredge in rates equivalent to their density on the channel bottom because they have no ability to escape (Larson & Moehl 1990, McGraw & Armstrong 1990).

Dredging activities associated with the PA are expected to have an effect on benthic prey availability and, to a lesser extent, prey availability in the water column. This disturbance could have an appreciable impact on the prey base at any given location, but the effect will be experienced over a limited area relative to the available habitat. Additionally, this effect is expected to occur for a short duration in a given year due to recolonization from locations in close proximity to the area of disturbance.

2.5.1.1.5.4.1.1 Salmonids Exposure and Risk

The spatial extent of listed species occurring contemporaneously with the dredging activities has been described previously (see section *2.5.1.1.1.1 Pile Driving*) and, for the most part, Chinook salmon are not expected to be present during dredging operations. Small numbers of Chinook salmon could be present, however, at either end of the in-water work window in some years. A larger proportion of steelhead would be present during dredging and could, therefore, be exposed to habitat that contains reduced prey. Given the extent of the activity, NMFS expects that the reduced prey availability caused by dredging will adversely affect a small proportion of winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, and CV steelhead.

2.5.1.1.5.4.1.2 Green Sturgeon Exposure and Risk

The timing of green sturgeon presence has been described in section *2.5.1.1.1 Acoustic Stress*.

The in-water work windows avoid the peak upstream migration period of green sturgeon (late February to early May) although both post-spawn adults and rearing juveniles may be present in the action area throughout the year.

Dredging activities associated with in-water construction of all PA components are expected to have an effect on benthic prey availability for green sturgeon. The loss of benthic food resources, such as amphipods or isopods, could reduce fish growth rates and increase the energy expended searching for food, depending on the density of the animal assemblages on the channel bottom. This would be more likely to occur to sturgeon, which are specialized benthic feeders. NMFS believes that small invertebrates—such as annelids, crustaceans (amphipods, isopods), and other benthic fauna—would be unable to escape the suction of the hydraulic dredge and be lost to the system.

Radtke (1966) inspected the stomach contents of juvenile green sturgeon (range: 200–580 millimeters) in the Delta and found food items to include mysid shrimp (*Neomysis awatschensis)*, amphipods (*Corophium sp.)*, and other unidentified shrimp. In the northern estuaries of Willapa Bay, Grays Harbor, and the Columbia River, green sturgeon have been found to feed on a diet consisting primarily of benthic prey and fish common to the estuary. For example, burrowing thalassinid shrimp (mostly *Neotrypaea californiensis*) were important food items for green sturgeon taken in Willapa Bay, Washington (Dumbauld et al. 2008). Populations of these organisms would be entrained by the hydraulic suction dredge, particularly small demersal fish and benthic invertebrates.

Repeated activities throughout the multi-year construction period may also delay or impair recruitment from surrounding areas before the following winter and spring migration periods through the action area. As these organisms occupy habitat types that are prone to disturbance under natural conditions, however, they would likely rapidly recolonize dredged areas by drifting and crawling from adjacent non-disturbed areas (Mackay 1992).

Dredging activities are expected to affect prey availability for green sturgeon throughout the Delta. This disturbance could have a significant impact to the prey base at any given location, but the effect will be experienced in a limited area relative to the available habitat surrounding each identified dredging location and for a relatively short duration. Additionally, suitable alternative feeding locations are likely within close proximity to the area of disturbance. Dredging activity occurrence and the associated disturbance of the existing benthic community, however, will cause an adverse effect to green sturgeon. Given the certainty and extent of the activity, NMFS therefore expects that the reduced prey availability caused by dredging will adversely affect a few individual green sturgeon.

2.5.1.1.5.5 Clearing and Grubbing at Construction Sites

Clearing and grubbing at construction sites is expected to result in some loss of riparian vegetation, including the NDD intake sites, barge landings, CCF, and HOR gate. Loss of riparian vegetation may also occur as an indirect effect of creating temporary access points to the river for construction. Some locations of cleared or cut riparian vegetation will be replaced with angular rock, or a structure or facility, and therefore will result in permanent loss. Other locations may be left to recolonize once construction activity has been completed, which may take one to five growing seasons depending on best management measures taken.

Riparian vegetation, specifically shaded riverine aquatic (SRA) habitat, provides overhead cover, resulting in shade and protection, slower flow velocities for resting spots, as well as providing substrate for food production such as aquatic and terrestrial invertebrates, for anadromous fish. A vibrant riparian corridor provides important water temperature cooling, especially in smaller streams. The loss of riparian vegetation can therefore increase predation rates (see section *2.5.1.1.6 Increased Predation Risk*) and increase water temperatures, which may result in decreased survival (see section *2.5.1.1.4 Increased Temperature*). Additionally, a degraded riparian corridor may reduce food production and feeding rates for juvenile anadromous fish.

Although loss of riparian vegetation at construction sites may reduce food inputs of aquatic or terrestrial invertebrates for fish, the extent is expected to be minimal. Also, because most juvenile salmonids are moving through, and not expected to rear long-term in the Delta, they are likely not adversely affected by riparian vegetation removal in these areas. Although green sturgeon juveniles may inhabit the Delta for longer periods, food base is more benthic-oriented and likely also not adversely affected.

2.5.1.1.6 Increased Predation Risk

Predator-prey interactions can be broken down into several fundamental steps between the prey and the predator. These steps include the rates of encounters between the predator and the prey, the rate at which the predator decides to pursue and attack the prey when detected, the rate at which the predator successfully captures the prey, and, ultimately, the rate at which the prey is consumed by the predator.

Each one of these steps is influenced by biological and physical factors in the surrounding environment such as prey abundance, spatial and temporal overlap of prey with the predator, habitat complexity, turbidity, and behavioral, physiological, and morphological adaptations that facilitate (predator success) or inhibit (prey avoidance) the predation process (Grossman et al. 2013, Grossman 2016). Although predation is frequently the proximate cause of mortality, the ultimate cause of mortality is often related to alterations in the physical or biological parameters of the habitat that prey occupy that enhance the rate of predation.

Predators and prey are affected by the habitat they occupy, which in turn influences the predator-prey interaction. First, predators and prey both partition habitat, which affects the rate of contact between predator and prey (the search and encounter rate). Secondly, habitat characteristics exert a direct effect on predator-prey behavior and interaction, primarily by reducing prey detection and improving the ability of prey to escape attack once detected by the predator (pursuit and attack rate) (Monroe 1997). Species partition the available habitat according to their intrinsic needs in response to their ability to use a variety of environmental conditions. Such environmental conditions include (Monroe 1997):

- Food availability for both predator and prey,
- Spawning habitat conditions,
- Availability of cover,
- Bottom substrate,
- Water depth,
- Distribution based on time of day and light conditions,
- Temperature and salinity preferences, and
- Water quality conditions (i.e., dissolved oxygen, pH, etc.).

Habitat also influences the behavior and survival of predators. Monroe (1997) states that habitat affects the behavior of predators primarily by:

- Separating predators and prey (habitat partitioning),
- Limiting visual contact between predator and prey, and
- Making a successful attack more difficult for predators than a successful escape by prey.

Locating prey appears to be primarily a visual function in most piscine predators (Dunbrack and Dill 1984), although there are other sensory forms that have been observed in prey detection (for example, olfaction in catfish, electrosensory detection in sharks). Because prey detection, particularly for predators common in the Delta and Central Valley waterways—such as striped bass, pike minnow, and largemouth bass—is most often a function of visual contact, any habitat characteristics that affect vision could be considered "cover" for prey species (Monroe 1997). Therefore, cover may include:

- turbidity and shade, which limit light penetration,
- vegetation and other physical structures that interrupt the line-of-sight from predator to prey, and
- background color or texture that "masks" or conceals the prey from detection by the predator.

Finally, because predators also vary in their physiology, protection conferred by one form of habitat may make prey vulnerable to another predator species. For example, avoiding heavily vegetated channel margins (e.g., *Egeria* beds) and remaining in open water may confer protection on prey species from ambush predators (e.g., largemouth bass), but makes them more vulnerable to attacks by a chase predator suited for open water habitat (e.g., striped bass).

Just as habitat affects the ability of prey to survive, habitat qualities also affect the success of predators to detect or capture prey and include (Monroe 1997):

- density and extent of structures that affect both detection and success of predator attacks,
- presence of barriers—such as dams with fish ladders, gates, or other structures—that can concentrate prey and predators and thus increase predator-prey contact rates,
- light, which affects prey detection,
- turbidity, which affects detection distance of prey,
- prey behavior such as schooling, swimming speed, or choice of habitat,
- temperature, which affects the activity level of both predator and prey, and
- stressors, such as contaminants, that can reduce prey growth rate (which keeps prey at a more vulnerable size for a longer period of time) or slows the response time and swimming speed of prey (and therefore reduces the ability of prey to escape).

Finally, because fish are highly adaptable, the response to habitat changes and quality are not always straightforward and linear and thus may not always be completely predictable, particularly on a shorter time scale. In general, though, habitat that is complex and offers a multitude of different niches provides for a more diverse biological community (Grossman et al. 2013, Grossman 2016).

In a stable, undisturbed, functioning habitat, multiple species can occupy the same general area by each species occupying a particular ecological niche, thereby minimizing direct competition between species and having a balanced predator-prey interaction. This is particularly true in habitats where predators and prey have co-evolved with each other. This relationship does not exist or is compromised when habitat is altered or nonnative species invade a new habitat, causing a loss of equilibrium among the species inhabiting it.

The Delta and Central Valley waterways are currently highly altered and disturbed habitats. In the aquatic ecosystems of the Central Valley and Delta waterways, widespread habitat alteration has occurred over the last 150 years including (Vogel 2010, Cloern and Jassby 2012, Demetras et al. 2010, Sabal el al. 2016, Wiens et al. 2016):

- numerous invasions by non-native species that alter physical habitat and food webs,
- alterations of hydrologic regimes, temperature regimes, and turbidity levels,
- loss of wetlands and riparian areas,
- anthropogenic changes in regional waterways due to physical structures such as levees, dams, channelized waterways, and water diversions, which in combination result in changed hydrodynamics and ambient flows,
- discharge of toxins, nutrients, and other contaminants, and
- changes in climate affecting precipitation patterns and temperatures.

The PA will create numerous alterations to the local aquatic habitat that will modify the predator–prey interaction in favor of the predator. The PA will modify existing hydrodynamics, turbidity, riparian and littoral areas at the construction sites and introduce novel elements such as noise and vibration into the adjacent waterways.

Examples of habitat modification created by the PA actions include the following:

- reduction in sediment load in the Sacramento River due to the NDDs, which will impact turbidity levels farther downstream in the tidally mixed area, thus increasing the detection distance of prey by predators,
- increased noise and activity along the margins of the river channels due to construction activities that may force prey to abandon the shoreline habitat and occupy the open water habitat in the construction areas, thus making them more vulnerable to predators,
- increases in ambient noise levels due to construction activities that may mask the approach of predators, reducing the ability of prey to avoid attacks,
- increases in local turbidity levels to high levels due to bank construction activities or dredging that may force prey from their preferred habitat into more risky environments, increasing the vulnerability to predator detection,
- construction of large in-water structures as part of the PA that may attract predators or concentrate prey and predators into confined spaces, thereby increasing the likelihood and duration of predator-prey interactions,

- alterations of ambient flows or circulation patterns that may increase the length of predator-prey interactions due to slower migration rates or disorient prey thereby making them more vulnerable to attack, and
- reduction of shoreline cover, riparian areas, and submerged vegetation, thereby increasing the vulnerability to detection by predators.

2.5.1.1.6.1 Pile Driving

Pile driving is expected to create environmental conditions that may cause fish to be:

- Injured due to barotrauma brought on by high levels of sound pressure related to the pile-driving actions, thereby altering the fish's swimming ability and behavior and making them more noticeable to predators and less likely to successfully avoid predator attacks.
- Less able to detect the approach of a predator by masking the sounds of the predator with elevated ambient noise levels directly related to the pile-driving actions.
- Distracted and direct its attention away from the approach of a predator in its surroundings and thus compromise its ability to successfully avoid a predatory attack.
- More likely to avoid nearshore areas adjacent to pile-driving activities and migrate through areas of deeper water with less areas of refugia from predators, thereby increasing their visibility to predators and increasing their risk of predatory attacks by open water predators.

2.5.1.1.6.1.1.1 North Delta Intake Locations

Pile driving and associated anthropogenic noise at the NDD intake locations (see section *2.5.1.1.1.1.1 North Delta Intake Locations* for details) are expected to increase predation risks to juvenile salmonids and green sturgeon present during the in-water work window, June 1 through October 31.

2.5.1.1.6.1.1.1.1 Chinook Salmon Exposure and Risk

Pile driving and associated anthropogenic noise at the NDI locations is expected to increase predation risk to juvenile salmonids. Small numbers of juvenile SR winter-run Chinook salmon, CV spring-run Chinook salmon, and fall-run Chinook salmon may be present at either end of the in-water work window in some years, which may delay the migrations of those individuals and which may expose individuals to pile-driving-induced noise and an associated increase in predation risk.

In October, about two percent of juvenile SR winter-run Chinook salmon are expected to be found in the vicinity of the NDI, while in June less than two percent of juvenile CV spring-run Chinook salmon could be migrating past the NDI locations. DJFMP beach sein and trawl data from the last 10 years (2006 through 2015) indicate that about 0.8 percent of juvenile fall-run Chinook salmon would be found near the NDI project site in June through October. A very small proportion of winter-run and spring-run and a medium proportion of fall-run Chinook salmon juveniles present are expected to be adversely effected through the increased risk of predation caused by pile driving in the vicinity of the NDI locations.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run and late fall-run Chinook salmon due to the overlap in their upstream migration timing with the in-water work window (see section *2.5.1.1.1.1.1.1.5 Fall/Late Fall-run Exposure and Risk*). No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the NDD location. Furthermore, NMFS does not anticipate that adult Chinook salmon would experience any changes in predation risks due to their exposure to elevated sound pressure levels related to the pile-driving actions. Therefore, adversely effects are not expected.

2.5.1.1.6.1.1.1.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the NDD locations has been described in section *2.5.1.1.1.1.1.3 Steelhead Exposure and Risk.*

The in-water water work window overlaps with a substantial proportion of the adult upstream migration. As previously assessed for adult Chinook salmon, however, NMFS anticipates that there will be no changes in the predation risks for adult fish due to exposure to elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little if any increased predation risk due to pile-driving actions at the NDD locations.

There is little overlap between the timing of juvenile steelhead migration and the in-water work window for the NDD location. NMFS estimates that less than one to two percent of the juvenile population will be moving past the NDD locations during pile-driving actions. While there is some increased risk of predation because of fish being exposed to the pile-driving stressors described above, the larger size of emigrating steelhead smolts compared to Chinook salmon will provide some minimization in this risk. Overall, a small proportion of juvenile steelhead are expected to be exposed to the pile-driving actions, which is likely to increase predation risk. Therefore, a small proportion of juvenile steelhead are likely to be adversely affected.

2.5.1.1.6.1.1.1.3 Green Sturgeon Exposure and Risk

The overlap of green sturgeon presence with the occurrence of pile driving activity has been previously described in section *2.5.1.1.1.1 Pile Driving* as it pertains to the acoustic effects experienced by green sturgeon encountering pile driving activity during the in-water work windows.

Generally speaking, juvenile sDPS green sturgeon are much more likely to experience increased predation throughout the Delta than adults or sub-adults owing to the difference in size. It is also worth noting, however, that juvenile green sturgeon may be inherently less susceptible to predation than other fishes because of the deterrence afforded them by the presence of protective scutes on their skin. Nevertheless, juvenile green sturgeon have the potential to be present in all waters of the Delta during every month of the year; therefore, a medium proportion will be exposed to an increased risk of predation during the pile driving in-water work window at the NDD locations. As a result, a small proportion of green sturgeon is likely to be adversely effected through displacement from nearshore habitat and cover, injury as a result of barotrauma, or otherwise compromised by acoustic-related stress from anthropogenic noise associated with pile driving as described earlier in this section.

2.5.1.1.6.1.1.2 Clifton Court Forebay

The construction in-water work window for the CCF is proposed from July 1 to November 30. Pile driving and associated anthropogenic noise at the CCF location is expected to create environmental conditions that are likely to increase predation risks to juvenile salmonids and green sturgeon that are present and exposed to the sound field. The stressors related to the increase in predation risks have been described above for the NDD locations and will also apply to the CCF location. The acoustic effects of pile driving are described in section *2.5.1.1.1.21 Pile Driving Acoustic Stress* above.

In summary, the extent of the 150-dB RMS threshold will cover the vast majority of the CCF waterbody when pile-driving actions are taking place in the forebay. The extent of the forebay that will exceed the 187-dB SEL threshold is approximately 25 percent of the width of the forebay when the cofferdams are installed along the perimeter of the forebay and approximately 45 percent of the width of the forebay when the sheet piles are driven along the partition dike separating the forebay into two waterbodies.

Fish exposed to sound pressure in excess of the 150-dB RMS threshold are expected to be vulnerable to masking sounds of approaching predators and to be distracted by the additional noise in the surrounding environment. Fish within the threshold of 187-dB SEL are more likely to suffer injuries due to barotrauma and, therefore, become more susceptible to predation through reduced fitness and their ability to escape predation attacks.

2.5.1.1.6.1.1.2.1 Chinook Salmon Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook into CCF during construction activities, there is the potential for adverse effects from increased risk of predation. Extending in-water construction activities into November results in potential exposure of juvenile spring-run Chinook salmon (yearling smolts) and winter-run Chinook salmon (young-of-the year). San Joaquin River-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations. Less than one percent of fall-run Chinook salmon juveniles would be expected to be present during the work window.

Although salvage data from 1993 through 2011 indicate very little to no winter-run and spring-run would be present in the CCF during the in-water work window, there is some likelihood that a few may be there towards the very end of the work window.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run and late fall-run due to the overlap in their upstream migration timing with the in-water work. No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the CCF location. Furthermore, NMFS does not anticipate that adult Chinook salmon would experience any changes in predation risks due to their exposure to elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult Chinook salmon will experience little if any increased predation risk due to pile-driving actions at the CCF locations.

2.5.1.1.6.1.1.2.2 Steelhead Exposure and Risk

Pile driving in CCF is not expected to appreciably increase the predation risk for juvenile steelhead present in the forebay. Although this water body will be accessible to both CCV steelhead juveniles from the Sacramento River basin via an open DCC gate and to fish emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries during the proposed in-water work window, it will likely be in low numbers. Based on monitoring data from the Delta and salvage data from the SWP and CVP fish collection facilities, less than one percent of the annual juvenile emigration is expected to occur during the proposed work window. Most juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location. As a few individual juvenile steelhead are likely to be present during the in-water work window due to the timing of emigration, they would enter the forebay and be exposed to increased predation risks due to pile driving. A small proportion of juvenile steelhead are likely to be adversely affected.

The CCF location on Old River is accessible to adult CCV steelhead populations from the Sacramento River basin, east side tributaries, and the San Joaquin River Basin. The likelihood of fish from the Sacramento River being present, however, diminishes with distance from the main stem of the San Joaquin River. It is expected that the timing of adult presence at the CCF location will be later than that observed for the North Delta due to its southern Delta location and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population.

Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January based on data from the Stanislaus River fish weir. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through November with the proposed in-water work window. As previously assessed for adult Chinook salmon, however, NMFS anticipates that there will be no changes in the predation risks for adult fish due to exposure to the elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little, if any, increased predation risk due to pile-driving actions at the CCF locations.

2.5.1.1.6.1.1.2.3 Green Sturgeon Exposure and Risk

As described in section *2.5.1.1.6.1.1.4 Barge Landings Locations*, the risk of predation to adult and sub-adult sDPS green sturgeon is practically non-existent throughout the action area because of the relative size of these fish to the common predatory species typically found in the Delta, as well as the presence of protective scutes on their skin that act as a natural deterrent to being preyed upon in general. Regarding the potential for increased exposure of juvenile green sturgeon to the risk of predation as a result of pile driving activity at CCF, NMFS expects that very few, if any, juvenile green sturgeon will be adversely affected by this particular stressor in consideration of the uniformity and relatively degraded quality of the habitat conditions at this location.

2.5.1.1.6.1.1.3 HOR Gate

The construction in-water work window for the HOR Gate is proposed from August 1 to October 31. Pile driving and associated anthropogenic noise at the HOR gate location is expected to create adverse environmental conditions that will increase predation risks to juvenile salmonids and green sturgeon that are present and exposed to the sound field. The stressors related to the increase in predation risks have been described above for the NDD locations and will also apply to the HOR gate location.

The acoustic effects of pile driving are described in section *2.5.1.1.1.1 Pile Driving* above.

In summary, the extent of the 150-dB RMS threshold and the 187-dB SEL threshold overlap and will cover the entire width of the Old River channel at the HOR gate location and extend up to 1,500 feet up and down river until the alignment of the river channel blocks further propagation of the sound path. Thus, any fish moving through Old River past the gate location will likely be injured or killed due to the magnitude of the sound pressure field that exists in this confined space.

Fish moving upstream in the mainstem channel of the San Joaquin River will also be exposed to the high sound levels as they pass the Head of Old River junction, but the distance that this intense field is present in the San Joaquin River is relatively short, and fish are expected to pass through relatively quickly. Fish within the threshold of 187-dB SEL are more likely to suffer injuries because of barotrauma and, therefore, become more susceptible to predation through reduced fitness and their ability to escape predation attacks.

2.5.1.1.6.1.1.3.1 Chinook Salmon Exposure and Risk

Pile driving at the Head of Old River Gate is not expected to increase predation on juvenile SR winter-run Chinook salmon, juvenile CV spring-run Chinook salmon, or juvenile fall-run Chinook salmon due to a lack of overlap in the timing of juvenile migrations and pile-driving actions.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run Chinook salmon because of the overlap in their upstream migration timing with the in-water work window (see section *2.5.1.1.1.1 Pile Driving*). No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the HOR gate location. Furthermore, NMFS does not anticipate that adult Chinook salmon would experience any changes in predation risks due to their exposure to elevated sound pressure levels related to the pile-driving actions. There is a high certainty that adult Chinook salmon will experience little if any increased predation risk due to pile-driving actions at the HOR gate locations.

2.5.1.1.6.1.1.3.2 Steelhead Exposure and Risk

Pile driving in Old River at the HOR gate location is not expected to appreciably increase the predation risk for juvenile steelhead. In summary, juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Therefore, exposure is unlikely. A few may be present, however, at the very end of the work period.

Based on regional monitoring data and salvage data from the SWP and CVP fish collection facilities, less than one to two percent of the annual juvenile emigration from either basin is expected to occur during the proposed work windows in 2020 and 2021. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location. It is not expected that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate, even though juvenile CCV steelhead from this basin are present at the CVP and SWP salvage facilities. There is a medium to high certainty that few individual juvenile steelhead will be present during the in-water work window due to the timing of emigration.

The HOR gate location on Old River is accessible to adult CCV steelhead populations from the Sacramento River basin, east side tributaries, and the San Joaquin River Basin. As previously assessed for adult Chinook salmon, however, NMFS anticipates that there will be no changes in the predation risks for adult fish due to the exposure to the elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little if any increased predation risk due to pile-driving actions at the CCF locations.

2.5.1.1.6.1.1.3.3 Green sturgeon

As discussed in the previous sections *2.5.1.1.6.1.1.3 HOR Gate* and *2.5.1.1.6.1.1.2.3 Green Sturgeon Exposure and Risk*, the probability of juvenile sDPS green sturgeon experiencing increased rates of predation is limited by the presence of bony scutes on their skin, which makes them a less desirable prey species than other fish. There is little evidence to suggest that the density of their numbers in the vicinity of the HOR would result in an increased risk of predation during the in-water work window. For these reasons, NMFS considers the risk of increased predation to sDPS green sturgeon as a result of pile driving activity at the HOR gate unlikely to result in adverse effects.

2.5.1.1.6.1.1.4 Barge Landings Locations

Barge landings will be constructed at each TBM launch shaft site for loading and unloading construction equipment, materials, fill, and tunnel spoils. A total of seven barge landings are currently proposed throughout the Delta. The locations are described in section *2.5.1.1.1.1.4 Barge Landing Locations*.

Each barge landing will require pile driving 107 steel pilings to support overwater dock structures during the proposed in-water work window of August 1 and October 31 when most listed species are least likely to occur in the action area. Pile driving and associated anthropogenic noise at the barge landing locations are expected, however, to create adverse environmental conditions that will increase predation risks to juvenile salmonids and green sturgeon that are present and exposed to the sound field.

Stressors related to the increase in predation risks have been described above for the NDD locations. It is expected that the diverse locations of barge landings will increase the potential for exposure to migrating fish because the sites are on main distributaries of the Delta in locations that serve as migratory corridors for listed salmonids and green sturgeon. The only exception is Snodgrass Slough, which is situated off of the main migratory corridors in a dead-end slough.

The extent of the sound pressure fields at each of the barge landing locations is given in section *2.5.1.1.1.1.4 Barge Landing Locations*. In general, the distance to the 187-dB SEL threshold will block channels within several hundred to several thousand feet at each landing location, creating areas where barotrauma injuries are likely. Reductions in fitness and swimming ability will enhance the vulnerability of affected fish to predation.

Similarly, the distance to the 150-dB RMS threshold for behavioral modifications will affect a greater area of the Delta channels surrounding the barge landing locations and create conditions in which the environmental sounds of approaching predators are masked or the prey are distracted from detecting approaching predators. This will lead to increased vulnerability to predation.

2.5.1.1.6.1.1.4.1 Chinook Salmon Exposure and Risk

Pile driving during construction of the barge landing locations is not expected to cause increased predation to juvenile CV spring-run Chinook salmon, but may expose a small proportion of SR winter-run, late fall-run, and fall-run Chinook salmon to increased predation.

Based on DJFMP beach seine and trawl data 2006 through 2015, it is expected that about two percent of juvenile population of SR winter-run Chinook salmon will have begun migrating through the Delta in October and may be present in the vicinity of the Snodgrass Slough barge landing location. A small proportion of winter-run, late fall-run, and fall-run Chinook salmon juveniles are expected to experience an adverse effect of increased risk of predation caused by pile driving in the vicinity of the barge landing location.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run and late fall-run because of the overlap in their upstream migration timing with the in-water work window (see section *2.5.1.1.1.1 Pile Driving*).

No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the barge landing locations. Furthermore, NMFS does not anticipate that adult Chinook salmon would experience any changes in predation risks due to their exposure to elevated sound pressure levels related to the pile-driving actions. There is a high certainty that adult Chinook salmon will experience little, if any, increased predation risk because of pile-driving actions at the barge landing locations.

2.5.1.1.6.1.1.4.2 Steelhead Exposure and Risk

The majority of juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Therefore, it is expected that very little overlap will occur, resulting in exposure to pile driving activities.

Based on regional monitoring data and salvage data from the SWP and CVP fish collection facilities, less than one to two percent of the annual juvenile emigration from either basin is expected to occur during the proposed in-water work windows. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location.

The various locations of the barge landings throughout the Delta waterways are accessible to adult CCV steelhead populations from the Sacramento River basin, east side tributaries, and the San Joaquin River Basin. The in-water water work window overlaps with a substantial proportion of the adult upstream migration for the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January based on data from the Stanislaus River fish weir. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through October with the proposed in-water work window. As previously assessed for adult Chinook salmon, however, NMFS anticipates no changes in the predation risks for adult fish because of the exposure to elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little, if any, increased predation risk due to pile-driving actions at the barge landing locations in the Delta.

2.5.1.1.6.1.1.4.3 Green Sturgeon Exposure and Risk

As described in the preceding sections characterizing the exposure and risk of sDPS green sturgeon to the threat of increased predation, the threat of increased predation as a result of exposure to anthropogenic noise from pile driving associated with the construction of barge landings is unlikely to occur. Nevertheless, juvenile green sturgeon have the potential to be present in all waters of the Delta during every month of the year, and so a small number of these fish will be exposed to an increased risk of predation during the in-water work window at all of the various locations where pile driving activity will occur in connection with the construction of the barge landings. This increase in exposure is not expected to result in adverse effects.

2.5.1.1.6.2 Barge Traffic

Details on the Barge Traffic component of the PA were described in section *2.5.1.1.1.2 Barge Traffic*.

2.5.1.1.6.2.1 Species Exposure and Risk

A description of the exposure and risk to species from increased predation as a result of increased barge traffic may be found in sections *2.5.1.1.1.2.1 Acoustic Effects of Barge and Tugboat Traffic*.

In summary, all listed anadromous fish will potentially be exposed to increased predation caused by barge-induced acoustic stress owing to year-round increase in barge traffic. Because most of the barge traffic will be utilizing the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the primary landing sites at Bouldin Island and the CCFB, those species or runs originating in the Sacramento River basin will have reduced exposure compared to those entering the Delta from the San Joaquin River. All species must pass through the western Delta and the waterways leading to the ocean where they will have some level of exposure to increased predation resulting from the noise generated by the barge tows during their movements through the Delta and San Francisco Estuary.

All juvenile salmonids and green sturgeon from the Central Valley will have some level of exposure to increased predation caused by the acoustic response effects of increased barge traffic sound. As previously described, Voellmy et al. (2014b) states that one way that elevated sound levels could affect a fish’s behavior is that noise could mask crucial acoustic cues such as those made by both prey and predators, thereby making that fish more susceptible to predation.

The increased level of anthropogenic noise will act as an additional stressor on the aquatic community, which in turn will expose salmonids and green sturgeon to an increased level of predation. Smolting juvenile salmonids from the Central Valley will be exposed to increased predation due to the wide spatial and temporal overlap of the acoustic stressors (i.e., increased barge traffic) with salmonid migrations. Adverse effects to a medium proportion of salmonids are expected to occur. As described earlier (section *2.5.1.1.6.1 Pile Driving*), the probability of juvenile sDPS green sturgeon experiencing increased rates of predation is limited by the presence of bony scutes on their skin, which makes them a less desirable prey species than other fish. Therefore, the likelihood of adverse effects are considerably lower than for salmonids or are even not likely to occur.

2.5.1.1.6.3 Interim In-Water Structures (Present During Construction)

The PA has numerous interim structures that have a high potential to increase the vulnerability of listed anadromous fish to predation because of their presence in the Delta's waterways. The PA will require the construction of multiple structures that will last for a finite period of time while the overall project is under construction. Following completion of the proposed project's infrastructure, these interim structures will either be removed completely from the water or modified to have a benign presence in the aquatic environment (i.e., cutting off pilings or sheet piles at the mudline).

The PA has several interim structures that can be separated into a two main categories for in-water structures: cofferdams constructed with sheet piles and pilings to support docks. Each category will have specific effects related to their structures. The effects of bulkheads, piers, pilings, and other over- and in-water structures on salmonids in the northwest were reviewed by Kahler et al. (2000) and Carrasquero (2001).

Cofferdams

Cofferdams will be constructed at all three North Delta intakes to isolate the construction area from the Sacramento River for the construction of the fish screens. Likewise, cofferdams will be constructed at the HOR gate location to isolate work areas to construct the gates, boat lock, and fish ladder within the live river channel of Old River. Several cofferdam structures will be constructed in the CCF to allow for construction of earthen embankments around the perimeter of the forebay and to separate the NCCF from the SCCF, construction of the NCCF siphon underneath the inlet to the intake channel, and the construction of the channel through the currently existing southern embankment to allow flooding of the newly constructed expansion area of the SCCF.

Cofferdams are typically built by pile driving steel interlocking sheet piles into the substrate, creating a vertical wall (a bulkhead) with little complexity or features into areas below the waterline and away from the bank.

There are no refugia for small prey size fish to hide from predators adjacent to the vertical steel wall. Kahler et al. (2000) and Carrasquero (2001) described the effects of vertical bulkhead or retaining walls such as cofferdams. These structures tend to be in deeper water, primarily because the structures are usually placed below the ordinary high water mark and the space behind them dewatered for construction purposes. This effectively pushes the shoreline out from its original location resulting in a corresponding increase in water depth along the face of the structure outside of the shallow littoral zone.

Given that out-migrating juvenile salmonids (particularly Chinook salmon) use shallow-water habitats for rearing, foraging, and migration, retaining walls may potentially disrupt juvenile salmonid migration. In turn, the cumulative impact of this migration disruption may be an overall reduction in survival rate because forcing juveniles into deeper water potentially affects their survival by limiting prey resource availability along the shoreline (shallow littoral zone), thereby decreasing their feeding success and growth rate, and also by increasing their exposure to predators in deeper water, hence increasing the predation rate.

Vertical bulkheads or retaining walls also lack habitat complexity, which offers little critical refuge from predators along the face of the structure. In the case of Delta waters, this increases the exposure to predators such as striped bass, which are visual predators that cruise in the open waters of mid channel and will opportunistically prey on fish “forced” out into the mid-channel open water by the shoreline cofferdam structures.

Furthermore, the hard vertical walls associated with the cofferdams have indentations in them created by the design of the sheet piles. The PA describes the type of sheet piles to be used as AZ-28-700 sheet piles. These piles are interlocking and create a depression that is approximately 18 inches deep by 40 inches wide. The depressions are large enough for larger predators such as black bass, pikeminnows, or catfish to hide in and ambush small fish such as salmonids passing along the face of the vertical sheet pile wall.

In addition to these depressions, the vertical structure allows for some level of shading along the face of the wall, which further camouflages predators holding there from prey moving along the wall in waters lit by the sun. Such shaded areas create hiding areas for predators and prey that conceal them from fish in the lighted zone outside of the area impacted by the shaded area. Such behavior by fish creates a temporal and spatial overlap of predators and prey in the shaded zone, as well as enhancing the success of predator ambush attacks on prey outside of the shaded zone (Kahler et al. 2000, Carrasquero 2001).

Pilings

Each piling will provide both structure and shade in an offshore environment. This will likely attract both predators and prey. The vertical pilings will provide alterations to the local flow field by disrupting the flow and creating eddies downstream of the piling and as well as other microhabitats associated with the disruption of sediment transport (Carrasquero 2001). In the review by Carrasquero (2001), it was reported that fish such as northern pikeminnow preferentially held in the backside eddies created by pilings in a riverine system. These pilings also attracted juvenile salmonids trying to avoid the local river currents and increased the overlap of predator and prey in a localized area, thus increasing the vulnerability of the prey to the co-occurring predator.

As noted previously for bulkheads and retaining walls, pilings are structurally simple and do not provide the necessary habitat complexity to function as prey refugia. Kahler et al. (2000) and Carrasquero (2001) also reported that bass were attracted to these structures. Largemouth bass appeared to be attracted to the shade produced by these structures, while male smallmouth bass appeared to use the structures (pilings) as a reference point for locating nests for spawning. The pilings will also support a large dock area that will provide thousands of square feet of shade per a landing dock structure for an extended period of time (years until the completion of the project). Shade can reduce the primary productivity of the impacted area by shading submerged aquatic plants. This may eventually cause the loss of any submerged aquatic plants beneath the dock structure.

Altered Hydraulics Due to Structures

The PA includes construction of cofferdams at both the HOR gate location and at the NCCF siphon structure. These structures have the capacity to alter the flow conditions in the waterways they occupy by decreasing the cross-sectional area of the channel, resulting in higher flow velocities and increased turbulence as water flows through the narrowed channel and around the structures. These hydraulic changes will create adverse conditions for any listed fish present in those areas and will increase vulnerability to predation. The higher velocity and increased turbulent flow field will disorient smaller fish, making them more susceptible to predators. The structures themselves, as well as the flow shears between different velocities, will create eddies and holding areas for predators to lie in wait for passing prey. These elements associated with the altered hydraulic conditions will adversely affect the survival of listed salmonids passing through these channels.

2.5.1.1.6.3.1 North Delta Intakes

2.5.1.1.6.3.1.1 Species Exposure and Risk

Because the cofferdams and barge landings with their multiple pilings and large deck structure will be left in place for at least a year—and typically for multiple years during the construction of the PA's infrastructure—they will overlap with both juvenile and adult salmonid and green sturgeon presence in the Delta waterways during their migrations through the Delta waterways.

Spatial occurrence for juvenile and adult salmonids and green sturgeon has been described previously in section *2.5.1.1.6.1.1.1 North Delta Intake Locations*. In summary, all adult and juvenile salmonids as well as green sturgeon must pass through the Sacramento–San Joaquin Delta waterways and the San Francisco Bay Estuary on their way to or from the ocean. The multiple cofferdams and barge landing locations are located in the North Delta, Central Delta, and South Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of salmonids and green sturgeon that may originate from both Sacramento and San Joaquin river basins.

Based on the spatial locations of the proposed cofferdams and barge landings and the 5.5- to 6-year duration of construction of the PA, all Central Valley populations of salmonids and green sturgeon will be exposed to interim structures during some portion of their life histories, many potentially several times during their life span.

The presence of the multiple interim structures in the Delta associated with the PA have a high likelihood of creating hotspot habitats for predators, which will in turn adversely affect salmonids and green sturgeon that come into contact with them.

The North Delta Diversions will have three large, temporary cofferdams built in front of the locations of the future fish screens and diversion points.

The cofferdam associated with Intake 2 is currently scheduled to be built in 2025 and mostly removed (cutoff near the mudline) in 2029, a period of 5 years. A portion of the cofferdam will remain as the training wall leading to the fish screens, and along the leading edge of the future screen structure forming the sill to the foundation for the screens. This cofferdam will have a linear length of 1,969 feet.

The cofferdam associated with Intake 3 will be built in 2024 and removed in 2027, a period of 4 years and will have a linear length of 1,497 feet. Most of it will be removed as described for Intake 2.

The cofferdam associated with Intake 5 will be built in 2022 and removed in 2026, a period of 5 years. It will have a linear length of 1,901 feet. This cofferdam will be removed in the same fashion as the previous two intake cofferdams. The total length of cofferdams present is

5,367 feet, and all three cofferdams will be present concurrently for at least 2 years (2025 and 2026) based on the proposed schedule.

The presence of the three cofferdams will have adverse effects on the survival of downstream emigrating salmonids (juveniles) in the Sacramento River. Impacts to adult migrants are less certain as they are less vulnerable to predation from resident predators in the Delta system. As described in the introduction to this section, cofferdams will reduce the available habitat for smaller migrating fish to use as refugia from predators. This will include salmonid smolts as they move downstream in the Sacramento River past the location of the three intakes.

It is expected that the presence of the intake cofferdams will increase the vulnerability of the emigrating juvenile salmonids to predation and ultimately lead to a higher mortality rate in this reach of their downstream emigration to the Delta over baseline conditions without the cofferdam structures. Because the majority of juvenile salmonids must use this reach of the Sacramento River to reach the Delta (but see exceptions above for flood conditions and passage through the Yolo Bypass), it is expected that all Sacramento River basin salmonids will be adversely impacted by these structures while they are in place, a period of up to 8 years (2022 to 2029).

The impact on the different life history stages of green sturgeon is less certain. Fine-scale habitat use by juvenile green sturgeon is unclear based on our current knowledge of the species. Whether individual green sturgeon juveniles will be forced away from the shoreline towards deeper waters by the cofferdams will depend on how these juveniles utilize nearshore habitat in the first place.

Predation on juvenile green sturgeon also has a large degree of uncertainty associated with it. It is likely that smaller individuals and more immature life history stages are vulnerable to predation by native and non-native piscine predators in the Delta system. Smaller individuals will have less formed protective scutes, which are believed to protect these fish from predatory attacks. The presence of interim in-water structures associated with the NDD will expose any individual green sturgeon juvenile passing through this reach of the river to a local predator field that is attracted to the in-water structures. It is expected that the density of predators associated with the structures will be greater than the surrounding area.

NMFS expects that increased predator-prey overlap in time and space associated with the NDD interim structures will adversely affect a medium proportion of juvenile winter-run Chinook salmon, spring-run Chinook salmon, late-fall-run, and fall-run Chinook salmon, as well as steelhead smolts given the multiple years of exposure to the interim structures and the documented presence at the NDD location during their downstream migrations to the Delta.

NMFS also expects that the increased presence of predators at the NDD interim structures will adversely affect juvenile green sturgeon. NMFS does not expect that the increased presence of predators associated with the NDD interim structures will adversely affect adult winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, steelhead, or green sturgeon.

2.5.1.1.6.3.2 Clifton Court Forebay

Construction activities at CCF are described in section *2.5.1.1.1.1.2 Clifton Court Forebay*.

2.5.1.1.6.3.2.1 Species Exposure and Risk

The effects of interim in-water structures on predation risk is described in the NDD section above. Because these structures are in place year round for multiple years, all anadromous fish that become entrained into the forebay will potentially be exposed to any adverse effects of the structure during their migratory movements.

Cofferdam structures associated with the NCCF siphon construction are expected to create predator habitat, which will expose fish to increased risk of predation as they enter the inlet to the intake channel leading to the Skinner Fish Protection Facility. For the same reasons described for the HOR gate cofferdam, predation of listed salmonids—including juvenile steelhead, winter-run, and spring-run Chinook, as well as juvenile green sturgeon and the unlisted fall-run and late-fall run Chinook salmon—is expected to increase due to the creation of vertical cofferdam walls without any refugia and the increases in flow velocity and turbulence associated with restricting the width of the inlet channel from the main forebay.

The cofferdam channel associated with the southern embankment to allow flooding of the expanded southern forebay is also expected to create predator habitat, exposing fish to increased risk of predation. Although a relatively short section of cofferdam will be built, the channel will have altered hydraulic conditions associated with it that are expected to enhance the predation of salmonids and green sturgeon.

As water levels increase and decrease in the main forebay due to export and radial gate operations, water will flow into and out of the newly created southern expansion area through the cofferdam lined channel. This will create the same scenario for increased flow velocities and turbulence as described below for the HOR gate and the NCC siphon locations. This condition is expected to last up to 2 years as the southern embankment is degraded and removed to form one continuous southern waterbody (the SCCF). During this period, this interim structure is expected to increase the vulnerability of listed salmonids, and juvenile green sturgeon to predation and increase the magnitude of loss associated with the operations of the SWP through its CCF operations.

Cofferdams that will form the cross forebay partition dike and the eastern and western embankment cofferdams are also expected to provide habitat for predators, which will increase predation risk of fish moving through CCF. The cumulative length of these three cofferdams is over 20,000 linear feet and will provide only vertical walls with no refugia for smaller fish to utilize.

As stated previously, the only features in these cofferdam walls are the large indentations created by the design of the interlocking sheet piles. These indentations are better suited for larger predators to hold in and hide from prey moving along the face of the cofferdam wall than for small fish to take refuge in.

In addition, the partition wall across the forebay will have two, 100-foot-wide gaps in its alignment during its first year of installation to allow water flow and circulation to occur while the southern earthen embankment is being removed. These channels will create their own localized velocity and turbulence conditions that will enhance the vulnerability of listed salmonids and green sturgeon to predation. The adverse effects of these hydraulic alterations have been previously described for the HOR gate and NCC siphons.

Finally, the partition dike cofferdam will act as a "fence" intercepting fish moving within the forebay and guiding them towards the intake channel to the west. This condition is likely to concentrate listed salmonids and green sturgeon in areas with increased predator concentrations, leading to higher predation rates than currently experienced in the forebay. It is expected that the eastern and western embankment cofferdams will be in place for two construction seasons (2027 and 2028), while the partition dike cofferdam will be in place for up to 4 years (2025 to 2028) while the cross forebay earthen embankment is constructed to separate the forebay into the NCCF and SCCF.

After the final earthen embankments are constructed, the sheet pile cofferdams are expected to be removed or cutoff at the mudline. During the period that the interim cofferdams are in place, the overall predation rate in the forebay is expected to increase due to the adverse habitat conditions created by the cofferdams.

NMFS expects that increased predator-prey overlap in time and space associated with the CCF interim structures will adversely affect a small proportion of juvenile salmonids given the multiple years of exposure to the interim structures and the documented presence at the CCF location during their downstream migrations through the Delta. NMFS expects that the increased predator-prey overlap in time and space at the CCF interim structures will also adversely affect a small proportion of juvenile green sturgeon. NMFS does not expect that the increased presence of predators associated with the CCF interim structures will adversely affect adult salmonids or green sturgeon.

2.5.1.1.6.3.3 HOR Gate

Construction of the HOR gate is expected to take two years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase.

All in-water construction work, including cofferdam installation, riprap placement, dredging, and barge operations, would be restricted to August 1 through October 31 to minimize or avoid potential effects on listed fish species. In addition, all pile driving requiring using an impact pile driver in or near open water (cofferdams and foundation piles) will be restricted to the in-water work period to avoid or minimize exposure of listed species to potentially harmful underwater noise levels. AMM 9 will be implemented to minimize impacts.

2.5.1.1.6.3.3.1 Species Exposure and Risk

The effects of interim in-water structures on predation risk is described in the NDD section above. Because these structures are in place year round for multiple years, all fish that migrate past the interim structure may potentially be exposed to any adverse effects of the structure during their migratory movements.

The presence of the cofferdams associated with the HOR gate construction will adversely affect salmonids originating in the San Joaquin River basin or any fish that stray from the Sacramento River basin. This includes steelhead, spring-run Chinook salmon, and fall-run Chinook salmon.

It is also possible that juvenile and adult green sturgeon will be present in these waters of the Delta. The two proposed cofferdams will be constructed in such a manner as to block one half of the Old River channel while that half of the gate structure is being built and then the other half when the remaining half of the gate is constructed in the subsequent year.

Each cofferdam installation is expected to last an entire year and will overlap with both adult salmonid upstream migrations and juvenile downstream migrations as smolts to the Delta. Green sturgeon may be present in the area year round. As described above, these cofferdams are expected to increase the vulnerability of emigrating salmonid smolts and rearing juvenile green sturgeons to local predators. Adverse effects to adult migrants are not expected to occur as they are less vulnerable to predation from resident predators in the Delta system.

NMFS also expects that not only will there be elevated predation related to the physical structure itself (vertical walls and loss of habitat refugia), but that the altered hydraulics associated with a structure blocking the flow of water in a tidally influenced channel will greatly benefit predator hunting efficiency. Predators such as black bass, pikeminnows, and striped bass can use holding areas in back eddies and hydraulic cushions created by the cofferdam structure and prey on the smaller fish disoriented by the increased velocities and turbulence present in the water flowing through the narrowed channel. Furthermore, because this is a tidally influenced channel, flow may potentially be bi-directional, creating these adverse conditions on both sides of the structure. These cofferdam structures will create adverse conditions in the Old River corridor for at least two years and will affect that proportion of migrating juvenile fish entering this channel on their downstream migration.

NMFS expects that increased predator-prey overlap in time and space associated with the HOR gate interim structures will adversely affect a small proportion of juvenile spring-run and fall-run Chinook salmon, as well as steelhead smolts given the multiple years of exposure to the interim structures and their documented presence at the HOR gate location during their downstream migrations to the Delta.

NMFS expects that the increased presence of predators at the HOR gate interim structures will also adversely affect juvenile green sturgeon present at that location. NMFS does not expect that the increased presence of predators associated with the NDD interim structures will adversely affect adult salmonids or green sturgeon.

2.5.1.1.6.3.4 Barge Landings

Construction of barge landings throughout the Delta will result in the degradation of nearshore habitat and increase the vulnerability of salmonids and green sturgeon to predation.

The PA describes at least eight potential locations for barge landings in the Delta, requiring over 800 pilings being placed into Delta waters to support these structures (107 pilings per barge landing). These pilings will create vertical structural habitat that is anticipated to create both velocity breaks and shade. Both predators and small fish such as salmonids are attracted to these habitat features created by the pilings, producing a potential overlap in their spatial occurrence. Pilings have little habitat complexity to offer refuge to small fish from co-occurring predators, and therefore the overlap in spatial occurrence is expected to increase predation vulnerability.

Additionally, the large overwater dock structures will create tens of thousands of square feet of shaded water that will adversely affect nearshore habitat as described previously, enhancing the vulnerability to predation and potentially reducing productivity by shading submerged aquatic vegetation.

The barge landings are scheduled to be built early in the project construction schedule to accommodate the off-loading of vital construction materials and equipment for the project. The barge landings are currently scheduled to be constructed in 2018 and 2019. They are expected to remain in place through the end of the project in 2029 when they are scheduled to be removed. Thus, the habitat alterations created by the pilings and over-water dock structures will affect 10-11 years of salmonid and green sturgeon populations moving through the Delta.

All but one of these proposed barge landings are on waterways frequented by salmonids and green sturgeon. The one landing that is located in waters not expected to be frequented by salmonids is Snodgrass Slough near the Intermediate Forebay location. All other locations are on significant waterways that serve as migration corridors or are immediately adjacent to such waterways. Therefore, it is highly likely that each year, salmonids and green sturgeon will pass through the waterways containing these barge landings and experience the adverse habitat conditions associated with the pilings and overwater structures.

2.5.1.1.6.3.4.1 Species Exposure and Risk

There is more uncertainty in how green sturgeon juveniles will respond to the barge landings. It is unknown whether juvenile green sturgeon will be attracted to the dozens of vertical pilings associated with each landing or will seek out the shaded waters under the dock platform.

Because green sturgeon juveniles are found in the waterways upon which the barge landings will be constructed, there will be some level of exposure to the predator field associated with each structure. The increased exposure is likely to enhance predation risk due to increased overlap in time and space with the increased density of predators associated with the structures.

NMFS expects that increased predator-prey overlap in time and space associated with the barge landing interim structures will adversely affect a small proportion of juvenile salmonids, given the multiple years of exposure to the interim structures and the documented presence at the various barge landing locations in the Delta during their downstream migrations through the Delta.

NMFS expects that the increased presence of predators at the barge landing interim structures will adversely affect a smaller proportion of juvenile green sturgeon than compared to salmonids. NMFS does not expect that the increased presence of predators associated with the barge landing interim structures will adversely affect adult salmonids or green sturgeon.

2.5.1.1.6.4 Clearing, Grubbing, and Maintenance

Loss of riparian vegetation is likely to occur during clearing and grubbing activities at construction sites, including the North Delta Intake sites, barge landings, CCF, and HOR. It may also occur as an indirect effect of creating temporary access points to the river for construction.

Some locations of cleared or cut riparian vegetation will be replaced with angular rock, or a structure or facility, and therefore will result in permanent loss. Other locations may be left to recolonize once construction activity has been completed, which may take one to five growing seasons depending on best management measures taken.

Riparian vegetation, specifically shaded riverine aquatic (SRA) habitat, provides vital overhead cover, resulting in shade and protection from predators. A vibrant riparian corridor provides habitat for juveniles to rest and hide from large predators. A degraded riparian corridor, especially one replaced with unnatural rock, cement, or metal, can adversely affect fish by increasing risk of being eaten by predators.

Although construction of the proposed project is likely to reduce riparian vegetation in the footprint of each new facility, and anadromous fish utilize these areas of the Sacramento River and Delta as a migratory corridor, the likely impact is expected to be so minimal that adverse effects of predation as a result of loss of riparian vegetation are not anticipated.

2.5.1.1.7 Physical Impacts to Fish

Physical disturbance may occur during PA construction activities such as pile driving, geotechnical boring, dredging, and cofferdam installation. The physical disturbance may be through displacement or disruption of normal behaviors. Displacement may temporarily expose juvenile fish to a greater risk of predation. Some adult and juvenile anadromous fish may experience up to 12 hours of migration delay due to construction activities. Repeated disturbance may potentially increase stress levels, which could result in lower reproductive success in adults and reduced growth in juveniles.

Direct injury or death may occur during instream construction activities if listed anadromous fish are present. Adult listed salmonids more easily avoid disturbance, although green sturgeon may approach an active construction area. Adults are especially vulnerable to injury from propellers on barges (strikes and entrainment) during barge traffic related to construction of the PA. Listed juvenile fish are especially vulnerable to crushing by construction equipment that enter the water for dredging and can become entrained into the dredger, geotechnical boring, cofferdam installation, and placement of nearshore riprap. Additionally, inside isolated cofferdams, the PA includes a “Fish Rescue Plan” to occur before dewatering, which will involve capture, transport, and release of fish present. Fish may be injured or killed during this process. Any fish not captured may become stranded and perish.

2.5.1.1.7.1 Pile Driving

Pile driving, as described in the PA, may potentially harm or harass salmonids and green sturgeon in the action area. The ways in which pile driving can affect species are:

- through pile-driving-induced acoustic stress (see section *2.5.1.1.1 Acoustic Stress*),
- the concentration and contaminant composition of resuspended sediments (see sections *2.5.1.1.2.1 Pile Driving* and *2.5.1.1.3.1 Pile Driving*),
- the reduction of prey availability (see section *2.5.1.1.5.1 Pile Driving*), and
- the increased exposure to potential predators (see section *2.5.1.1.6.1 Pile Driving*).

Pile driving may also result in physical impacts to fish (described here) that include direct injury or death through contact with driven piles as well as the displacement or disruption of normal behaviors.

It is expected that the effect of pile-driving-induced physical impacts to fish will not manifest in any substantial way as direct injury or death considering the extreme proximity required (physical contact) and that any effect at greater distance would be considered an acoustic stressor (see section *2.5.1.1.1 Acoustic Stress*). What is far more likely is that the effect of pile-driving-induced physical impacts to fish will occur as displacement or disruption of migration behaviors.

All pile driving is proposed to occur within the in-water work window. For species with migrations contemporaneous with the in-water work window for a particular location, those species may experience up to 12 hours of migration delay due to construction activities. Repeated disturbance may potentially increase stress levels, which could result in lower reproductive success in adults and reduced growth in juveniles.

2.5.1.1.7.1.1 North Delta Intake Locations

Section *2.5.1.1.3.1.1 North Delta Intake Locations* describes pile driving activities at these locations.

2.5.1.1.7.1.1.1 Salmonids Exposure and Risk

Pile driving at the North Delta Intake locations has the potential to cause physical impacts to juvenile salmonids. Small numbers of Chinook salmon and steelhead juveniles may be present at either end of the in-water work window in some years, which may delay their migrations. Exposure is expected to occur to a much larger proportion of adult CCV steelhead due to migration timing.

In October about two percent of juvenile SR winter-run Chinook salmon are expected to be found in the vicinity of the NDI. Less than two percent of CV spring-run Chinook salmon and less than one percent of the annual juvenile fall-run Chinook salmon population would be found near the NDD sites in June through October, and about one percent to two percent of CCV steelhead could be migrating past the NDI locations.

Adult Chinook salmon would not be expected to be found in the vicinity of the NDI during the in-water work window. Adult CCV steelhead may potentially be found within the Delta during any month, and, unlike Chinook salmon, steelhead can spawn more than once, so post-spawn adults (typically females) have the potential to move back downstream through the Delta after completing their spawning in their natal streams.

Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. The timing of the adult CCV steelhead migration may potentially expose fish returning to the Sacramento River basin to the physical impacts of pile driving. Larger fish are more physically able to move away from any disturbance and are less likely to be injured. Because of the potential exposure of a small proportion juvenile salmonids and adult CCV steelhead to pile-driving-induced physical impacts, some adverse effects are likely. Adverse effects, however, would likely be limited to stress, displacement, or delay.

2.5.1.1.7.1.1.2 Green Sturgeon Exposure and Risk

Juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta every month, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta. Because of the widespread and year-round presence of juvenile and sub-adult sDPS green sturgeon in the waters of the Delta, these life stages could be present in the vicinity of the NDI locations and could be exposed to physical impacts of pile-driving activities. Adverse effects to those present are expected to be limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon.

2.5.1.1.7.1.2 Clifton Court Forebay

Section *2.5.1.1.6.1.1.2 Clifton Court Forebay* describes pile driving activities at this location.

2.5.1.1.7.1.2.1 Salmonids Exposure and Risk

Pile driving at the CCF may result in physical impacts to salmonids. Extending in-water construction activities into November results in potential exposure of juvenile spring-run Chinook salmon (yearling smolts) and winter-run Chinook salmon (young-of-the year). Less than one percent of fall-run Chinook salmon juveniles would be expected to be present during the work window.

Juvenile steelhead may be present in CCF during pile driving, though less than one percent of the annual juvenile emigration is expected to occur during the work window. Adult steelhead may potentially be found within the Delta during any month of the year.

A small proportion of salmonids will be adversely affected by physical impacts from pile driving activities at the CCF. As described above in section *2.5.1.1.7 Physical Impacts to Fish*, however, any adverse effects are expected to be limited to stress, displacement, or disruption the normal behavior.

2.5.1.1.7.1.2.2 Green Sturgeon Exposure and Risk

Post-spawning adults, sub-adults, and juveniles may be present in the Delta during the late summer and fall months and could therefore become exposed to physical impacts of pile driving activities in the CCF during the in-water construction period. A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta. Adverse effects to those present are expected to be limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon.

2.5.1.1.7.1.3 HOR Gate

Section *2.5.1.1.6.1.1.3 HOR Gate* describes pile driving activities at this location.

2.5.1.1.7.1.3.1 Salmonids Exposure and Risk

Pile driving at the Head of Old River Gate has the potential to cause physical impacts to juvenile and adult salmonids. Although injury is not likely to occur, impacts may include displacement or disruption to their normal behavior.

During the in-water work window, adult CCV steelhead may be exposed to pile-driving activities at the HOR gate as they come from or go to the San Joaquin River. This also applies to less than one to two percent of the juvenile steelhead emigration from either basin.

Sacramento River winter-run Chinook salmon and CV spring-run Chinook salmon are not expected to be present during the in-water work window, although a few individual spring-run Chinook salmon juveniles may be exposed in October.

Adult late fall-run Chinook salmon are not expected to be present in the Delta during the in-water work window. Juvenile fall-run Chinook salmon may be exposed to activities especially in July and August, though likely only in small numbers.

Therefore, physical impacts of pile-driving activities at the Head of Old River Gate are expected to adversely affect a small proportion of juvenile and adult CCV steelhead, as well as a small number of individual juvenile spring-run and fall-run Chinook salmon.

2.5.1.1.7.1.3.2 Green Sturgeon Exposure and Risk

Juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta every month, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta.

Because of the widespread and year-round presence of juvenile and sub-adult sDPS green sturgeon in the waters of the Delta, these life stages could be present in the vicinity of the HOR gate and could be exposed to physical impacts of pile-driving activities. Adverse effects to those present are expected to be limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon.

2.5.1.1.7.1.4 Barge Landing Locations

Section *2.5.1.1.6.1.1.4 Barge Landings Locations* describes pile driving activities at these locations.

2.5.1.1.7.1.4.1 Salmonids Exposure and Risk

Pile driving during construction of the barge landing locations is not expected to cause physical injury to juvenile salmonids, but those present may experience displacement or disruption to normal behavior.

There will be seven barge landing locations throughout the Delta. For their construction, the action agency has proposed a reduced in-water work window of August 1 to October 31, which will further minimize salmonid exposure.

At the barge landing locations, adult and juvenile CV Spring-run Chinook salmon are not expected to be present during the in-water work window because it falls outside their migration period.

It is estimated that about two percent of juvenile population of SR winter-run Chinook salmon will have begun migrating through the Delta in October and may be present in the vicinity of the Snodgrass Slough barge landing location. Most landings are, however, outside of the migratory corridor for winter-run Chinook salmon.

Juvenile fall-run Chinook salmon may be exposed to pile driving in August, and adult late fall-run Chinook salmon in October, while adult fall-run and juvenile late fall-run Chinook salmon may be present the entire work window.

A large proportion of adult steelhead will be present during the in-water work window, potentially exposing up to 80 percent to pile-driving activities at barge landings. The exposure to emigrating juvenile steelhead is considerably less because less than one to two percent of the juvenile migration will occur over September and October.

With respect to physical impacts, adverse effects to salmonids present during pile driving activities at barge landings are expected to be limited to stress, displacement, or disruption of normal behaviors, which could lead to increased predation of juveniles (see section *2.5.1.1.6 Increased Predation Risk*) or decreased spawning success for adults.

2.5.1.1.7.1.4.2 Green Sturgeon Exposure and Risk

Green sturgeon juveniles and sub-adults may be present in the Delta at any time of the year, potentially exposing that species to physical impacts of pile-driving activities at barge landing locations. In addition, the timing of both adult and juvenile green sturgeon migrations back through the Delta and out to the ocean are highly variable. Therefore, exposure to physical impacts of pile driving may be high. Because direct injury is not likely, adverse effects will likely be limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon.

2.5.1.1.7.2 Dredging Entrainment

It is anticipated that most construction-related dredging will be done by hydraulic cutterhead dredges. The hydraulic cutterhead dredge operates by pulling water through the cutterhead assembly, upwards through the intake pipeline, past the hydraulic pump, and down the outflow pipeline to the dredge material placement site. The suction creates a field of entrainment around the head of the dredge intake pipe, which can result in adverse effects to fish. The size of the field of entrainment surrounding the cutterhead depends on the diameter of the pipeline, the power of the pump, and how deep the cutterhead is extended into the sediment layer.

In previous consultations regarding large-scale dredging projects for the Sacramento and Stockton DWSC, NMFS calculated the flow fields surrounding a cutterhead with either half the cutterhead exposed above the sediment surface or a quarter of the cutterhead exposed above the sediment surface. Using a dredger with a 15-ft/sec inlet pipe velocity (approximately equivalent to the dredger used for the DWSC maintenance dredging projects), the flows surrounding the cutterhead for the hemisphere exposure will have a velocity of 38 cm/sec at 0.5 meters from the intake. At 1.5 meters from the cutterhead, flow velocities are reduced to 4.2 cm/sec.

If the average size steelhead smolt is approximately 250 millimeters, then the flow velocity, even within 0.5 meters of the cutterhead, is still below the burst swimming speed of 10 body lengths (BL)/sec for steelhead (i.e., 250 cm/sec burst speed). Similarly, a winter-run Chinook salmon juvenile with an average length of 85 mm would still have sufficient burst speed capacity to overcome the intake velocity of the dredge (85 cm/sec burst speed) at the 0.5 meter distance.

The modeling conducted for those maintenance dredging projects using a quarter hemisphere flow field for a deeper entrenched cutterhead calculated that flow velocities will be 76 cm/sec at 0.5 meters and 8.4 cm/sec at 1.5 meters. Velocities within 0.5 meters of the cutterhead are still below the critical 10 BL/sec burst swimming speed for steelhead smolts, but are approaching the burst speed limits for smaller salmonids (Webb 1995).

It is therefore unlikely that either a steelhead smolt or a winter-run Chinook salmon juvenile that detects the presence of the cutterhead would be unable to escape its field of influence, unless its swimming ability was in some way compromised. Furthermore, most dredging will take place during the day and at times of the year (summer/fall) when juvenile salmonids are least likely to be present in the Delta. In addition, the NDD intake locations are in areas that are deeper than approximately 3 meters and frequently deeper (6–7 meters). It is not anticipated that steelhead or Chinook salmon smolts would be at this depth during the day while on their seaward migration, preferring to migrate in the upper reaches of the water column during the day, thus further insulating them from the effects of the flow fields surrounding the cutterhead. Adult salmonids that may encounter the hydraulic dredge would likewise be able to avoid and escape entrainment due to their greater swimming speed.

Modeling indicates that smaller salmonids may be at risk because the flow velocities may exceed the burst swimming capabilities of the fish. Earlier Corps studies of juvenile salmonid entrainment in the lower Fraser River, British Columbia, Canada indicated that dredging in confined waters, such as narrow constricted channels where fish occupied the entire channel, could result in substantial entrainment rates of salmon (Dutta and Sookachoff (1975) as cited in Reine and Clark 1998). Estimates of entrainment rates by hydraulic dredging ranged from 0.00004 to 0.4 percent of the total out-migration of fry and smolts (Arsenault (1981) in Reine and Clark 1998). The Corps report (Reine and Clark 1998) estimated that for chum salmon (*O. keta*), entrainment rates for hydraulic pipeline dredging were 0.008 fish/cubic yard of dredged material. The Corps report also concluded that for upland confined dredging material disposal, as is proposed for this project, entrainment mortality would be 100 percent.

In addition to salmonids, other organisms would be entrained by the hydraulic suction dredge, particularly small demersal fish and benthic invertebrates. The Corps report (Reine and Clark 1998) estimated that the mean entrainment rate of a typical benthic invertebrate—represented by the grass shrimp when the cutterhead was positioned at or near the bottom—was 0.69 shrimp/cubic yard, but rose sharply to 3.4 shrimp/cubic yard when the cutterhead was raised above the substrate to clean the pipeline and cutterhead assembly.

Similarly, benthic infauna, such as clams, would be entrained by the suction dredge in rates equivalent to their density on the channel bottom because they have no ability to escape. The loss of benthic food resources, such as amphipods or isopods, could reduce fish growth rates and increase the energy expended searching for food, depending on the density of the animal assemblages on the channel bottom. This would be more likely the case for sturgeon, which are specialized benthic feeders, but also could affect juvenile salmon and steelhead. (See section *2.5.1.1.5.4 Dredging* for more discussion.)

It is likely that small invertebrates—such as annelids, crustaceans (amphipods, isopods), and other benthic fauna—would be unable to escape the suction of the hydraulic dredge and be lost to the system. Also, many benthic invertebrates have pelagic, surface-oriented larvae. The loss, therefore, of these benthic invertebrates may reduce the abundance of localized zooplankton populations in the upper regions of the water column where juvenile salmonids migrate through the DWSC. The timing of the dredging cycle (summer-fall) may preclude forage base replacement by recruitment from surrounding populations prior to the following winter and spring migration period of juvenile steelhead and Chinook salmon through the dredging action area (Nightingale and Simenstad 2001).

2.5.1.1.7.2.1 Salmonids Exposure and Risk

Based on the timing of juvenile and adult Chinook salmon migration through the Delta from both the Sacramento and San Joaquin river basins described in section *2.5.1.1.1.1 Pile Driving*:

- Juvenile winter-run Chinook salmon are expected to be present in the Delta from October to April, while adult winter-run are present in the Delta between November and June.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May, with adult spring-run presence between January and June.
- Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August. Adults are present from July to December.
- Juvenile late fall-run Chinook salmon are expected to be present from July through September. Adult late fall-run Chinook salmon are expected to be present in the Delta from November through April.

Although the timing and location of in-water activities such as dredging are designed to minimize overlap with the majority of migrating listed juvenile and adult Chinook salmon, in some years, small proportions of the different populations may still be migrating through the action area during the in-water work window. NMFS expects that a few individual juvenile winter- and spring-run and adult winter-run Chinook salmon, some juvenile and adult fall-run Chinook salmon, and some juvenile late-fall run Chinook salmon present would be exposed to entrainment into the dredger cutterheads during dredging activities. Therefore, although some adverse effects are likely to occur, as explained above, this risk is considered to be low because:

- No winter-run juveniles or adults are expected in the south Delta at the barge landing locations, CCF, or the HOR locations during the in-water work windows;
- If present, few juvenile fish are expected to be near the bottom where the dredger is operating;
- If present, juvenile fish should be able to avoid and escape the inflow velocity to the cutterhead based on their burst speed swimming velocities; adults should be able to easily avoid the inflow velocity based on their size;

Based on the timing of juvenile and adult steelhead migration through the Delta from both the Sacramento and San Joaquin river basins described in section *2.5.1.1.1.1 Pile Driving*:

- Juvenile steelhead will begin to enter the northern Delta as early as September through December, but do not substantially increase in numbers until February and March.
- San Joaquin River basin juvenile steelhead occur throughout the winter and spring, but peak emigration occurs in April and May;
- Adult steelhead may begin to enter the Sacramento River from the Delta as early as June, but most immigration occurs from August through November, with a peak in September and October.
- Adult steelhead from the San Joaquin River basin enter the Delta starting in September, but peak in November through January.

NMFS expects that there will be a minor overlap of juvenile steelhead emigration with dredging activities in the fall and June, but that only a few individuals will be adversely effected. There is a substantial overlap of dredging activities with adult steelhead migration into the Sacramento River basin during the summer and fall period. The overlap of dredging activities with the adults from the San Joaquin River basin is considerably less because of the expected later timing of that upstream migration peak. Adverse effects to adult steelhead are not expected to occur. Adults should be able to easily avoid the inflow velocity to the cutterhead based on their size. Few individuals are anticipated in September and October when dredging activities are expected to be concluding. NMFS expects that the risk of entrainment for juvenile steelhead will be low due to the low likelihood of juvenile presence during the work window and the following factors:

- If present, few juvenile steelhead are expected to be near the bottom where the dredger is operating;
- Juvenile fish should be able to avoid and escape the inflow velocity to the cutterhead based on their burst speed swimming velocities.

2.5.1.1.7.2.2 Green Sturgeon Exposure and Risk

Although there is some uncertainty as to how sturgeon react to an approaching dredge, considering their benthic orientation there is a relatively high probability that some interactions between sturgeon and the suction head of the dredge will occur.

The Corps (2008) concluded the potential for entrainment of green sturgeon may be higher than for salmonids. Entrainment monitoring conducted during maintenance dredging operations in the Sacramento and Stockton DWSC, however, showed that very few sturgeon were ever entrained by the dredge. Recent laboratory studies of sturgeon behavior have demonstrated that green sturgeon have higher entrainment rates than salmonids, and do not exhibit avoidance behavior typical of salmonids near unscreened diversions, and that they may not be as adept at detecting disturbances in water velocity and altering their swimming direction to avoid them (Mussen et al. 2014).

Those findings suggest that sturgeon may also be more susceptible to entrainment into the suction head of the dredge. Adult and sub-adult sturgeon are expected to be able to swim away from the suction head of the dredge because of their size and corresponding swimming strength and speed, but juvenile green sturgeon are less likely to be able to overcome the sudden change in water velocities in the area immediately surrounding the suction head of the dredge and will likely become entrained and killed if they are in close proximity to it during operation.

Because of their year-round presence in the waters of the Delta, some juvenile sDPS green sturgeon will be present in the action area during the in-water work windows when dredging is scheduled to occur and could therefore be adversely affected by entrainment into the suction dredge. The rate of entrainment is difficult to ascertain, but will likely have a higher probability of occurring at the NDD and barge landings on the Sacramento River than at CCF, the HOR gate, or the south Delta in general.

2.5.1.1.7.3 Barge Propeller Injury and Entrainment

Barge operations, routes, and assumptions are described in section *2.5.1.1.1.2 Barge Traffic*.

As noted in section *2.5.1.1.1.2 Barge Traffic*, Reclamation and DWR indicated that the assumed length of tug boats will be 65 to 100 feet (19.8 to 30.5 meters) with a beam of approximately 35 feet (10.7 meters) and a draft of approximately 6 to 8 feet (1.8 to 2.4 meters).

To estimate the potential effects of increased barge traffic on listed species because of direct injury from propellers, NMFS assumed that propeller disc diameter is approximately 70 percent of the draft, or 50 to 70 inches (1.3 to 1.8 meters) in diameter. This corresponds to dimensions for typical tug boats operating in the Delta and San Francisco Bay. Tugs in the Bay and Delta typically use shrouded propellers (e.g., Kort nozzles). Three sizes of propellers that span the middle range of diameters were used for the effects assessment (1.3-, 1.5- and 1.8-meter diameter). These sizes correspond to ships with drafts from 1.86 to approximately 2.6 meters.

The increase in barge traffic to the multiple barge landing sites in the Delta will concurrently increase the number of salmonids and green sturgeon that will have encounters with the propellers of the tugboats pushing the barges.

Although the exact numbers of fish entrained into the propeller's zone of influence are impossible to determine, certain assumptions and modeling of the propeller entrainment zone can be made to give ranges for the numbers of affected fish. In order to make a simple assessment of the number of anadromous fish subject to propeller entrainment, NMFS determined the length of the route transited by ships in the San Joaquin River and Sacramento River channels, the range of ship propeller sizes, and then applied the recorded density of Chinook salmon in the Delta from published data provided by the USFWS to characterize the salmonid entrainment numbers for vessel traffic within the different routes. NMFS assumes that densities in the lower Sacramento DWSC downstream of Rio Vista would be similar to those seen at Chipps Island.

NMFS calculated the volume of water that is swept through the propeller disc during three different legs of the transit distance between the Port of Pittsburgh and the barge landings at Bouldin Island and CCF:

- Port of Pittsburg (RM 4) to Blind Point (River Mile 10),
- Blind Point (River Mile 10) to channel marker "42" (River Mile 20) at the mouth of the Seven Mile Slough,
- channel marker "42" (River Mile 20) to the barge landing site.

A reverse route was calculated from the Port of Stockton (River Mile 40) to the barge landings at Bouldin Island and CCF to represent this point of origin. For the route going from Chipps Island to the NDD Intake 2 construction site, the route was broken into two legs. The first leg went from Chipps Island to River Mile 14 on the Sacramento River, and the second leg from River Mile 14 to River Mile 41 where the NDD Intake 2 is located. River Mile 14 is the junction between the Sacramento Ship Channel and the natural channel of the Sacramento River upstream of Rio Vista. The volumes were simplified to be equivalent to the diameter of the propeller times the distance of each leg.

The model calculating the volume had to be simplified because specific information for the pitch of the propeller, the revolutions per minute of the propeller disc, the area of water in front of the shrouded propeller entrained into the propeller, and the variability of the speed of the engine during the tug's maneuvering of barges was unavailable.

NMFS also assumes that there are twin propellers on each tugboat, thus the volume swept by a single propeller disc is multiplied by two to give the cumulative volume per tugboat transit. These volumes were then multiplied by the different Chinook salmon and steelhead densities, as measured by the USFWS during their monitoring efforts at Chipps Island, Jersey Point, Prisoners Point, and Sherwood Harbor (Jonathan Speegle [USFWS, 2016] personal communication, P. Cadrett [USFWS, 2005] personal communication).

The products of these calculations were then adjusted for the projected rate of mortality for smolting salmonids between 85 and 250 millimeters long passing through the blades of a propeller or turbine (Gutreuter *et al.* 2003; Killgore *et al.* 2001; Dubois and Gloss 1993; Cada 1990; Holland 1986; Giorgi *et al.* 1988; and Gloss and Wahl 1983) to derive the number of salmon mortalities for one year's volume of barge traffic in the San Joaquin DWSC going to Bouldin Island or the CCF barge landings and the volume of barge traffic using the Sacramento River route to the NDD Intake 2 construction site.

NMFS used a mortality value of 40 percent for Chinook salmon, which would represent smolts between 85 and 120 millimeters, and 80 percent mortality for steelhead smolts that encountered the propeller resulting from direct death because of being struck by the propeller blade, death from the cavitation surrounding the blade, or delayed death following the encounter with the propeller.

Additional assumptions for calculating propeller entrainment are included in Table X in section *2.5.1.1.1.2Barge Traffic*:

- That each point of origin for barge traffic accounts for one third of the trips to Bouldin or the CCF barge landing site.
- Barges only travel on week days during the week, not on weekends for a cumulative 269 work days per year.
- Barge traffic to the NDD #2 intake location will only occur once per week (once every 5 work days).
- Number of estimated barge trips to Bouldin Island is 6689 trips over 6 years; 1,114.83 trips per year; 4.15 trips per day (one way) and 8.3 round trips per day over a 269-work-day year.
- Number of estimated one-way barge trips to CCF is 4,370 trips over 6 years, 728.3 trips per year; 2.7 trips per day one way and 5.4 trips per day round trip over a 269-work-day year.
- Chipps Island fish densities were used for the Sacramento River leg from Chipps Island to RM 14. Sherwood Harbor fish densities were used from RM 14 to RM 41 on the Sacramento River route to NDD Intake #2.
- Chipps Island fish densities were used for the San Joaquin River route from RM 4 to RM 10.

- RM 10 to RM 20 on the San Joaquin River used estimated fish densities determined from the ratio of Jersey Point fish densities to Chipps Island fish densities to determine monthly densities throughout the year.
- RM 20 to barge landings sites on the San Joaquin River used estimated fish densities determined from the ratio of Prisoners Point fish densities to Chipps Island fish densities to determine monthly densities throughout the year.

The zones of effects for water entrainment by the propellers (inflow zone) are calculated only for the diameter of a given set of propeller along the length of the ship channel from Pittsburgh or Stockton to the Bouldin Island or CCF barge landings or Chipps Island to NDD Intake 2. Studies by Maynord (2000) indicated that the inflow zone for barge tows on the Mississippi River extend slightly beyond the beam of the tow (about 20 percent wider than the beam of the tow from centerline). Therefore, NMFS calculations may be underestimating the true volume of water entrained by the tugboat’s propeller during its transit to the barge landings.

Similarly, NMFS does not have any data for potential avoidance of juvenile and adult salmonids to oncoming barge traffic. Data gathered by the USFWS trawls, however, should represent a reasonable approximation of fish density that a tug and barge would encounter in the channel. The trawling activities involve motorized vessels dragging a net through the channel’s waters, which creates a substantial disturbance within the water column. The speed of the trawl is quite slow, generally less than 5 mph, providing ample opportunity for fish to escape the net by either moving laterally or vertically in the water column. Oncoming barge traffic would be moving at a faster rate (5 to 8 miles per hour) than the trawl vessels and would take up a greater percentage of the channel’s cross section. The draft of the barge tow would be similar to that of the trawl (approximately 3 meters), but would have a greater beam (15 to 17 meters) than the width of the mouth of the trawl net (maximum of 9.14 meters), which would necessitate moving greater lateral distances to avoid the oncoming barge compared to the mouth of the mid-water or Kodiak trawl net.

The barge tows are moving through the channel at 5 to 8 miles per hour (2,200 to 3,600 millimeters per second). This is equivalent to approximately 24 to 40 times the length of an average sized Chinook salmon smolt (90 millimeters) and 10 to 16 times the length of an average steelhead smolt (approximately 220 millimeters). A smolt located along the sailing line of a barge tow would have to swim at least 9,144 millimeters (30 feet) to escape the predicted zone of inflow for a barge with a beam of 15.24 meters (50 feet). The maximum burst swimming speed for juvenile salmonids is approximately 10 times their body length (Webb 1995) or 900 millimeters per second for Chinook salmon and 2200 millimeters per second for steelhead smolts. At maximum swimming velocity, a 90-millimeter Chinook salmon smolt would take 10 seconds to cover the distance from the ship’s sailing line to the outside margins of the zone of inflow. Ten seconds is within the limits of salmonid burst swimming duration (approximately 15 seconds); however, any fish that exerted this type of energetic output would be fatigued by the activity.

For the larger steelhead smolt, it would only take about 4.5 to 5 seconds to cover the same distance, and the fish would be less fatigued by the escape. In 10 seconds the vessel would have moved 22,000 to 36,000 millimeters (22 to 36 meters) forward along its course of travel. Any Chinook salmon smolt along the centerline of travel would have to initiate its escape response at least 40 meters ahead of the ship in order to ensure its movement out of the inflow zone. For the larger steelhead smolt, the barge will have moved about 10,000 to 16,200 millimeters (approximately 10 to 16 meters) forward in 4.5 seconds. Although a salmonid would easily be able to detect the ship's propulsion system at these distances, data is lacking as to the critical distances at which a salmonid would exhibit escape responses as a result of the increasing noise levels. At 40 meters in front of the bow of an oncoming barge, the propulsion unit of a ship and its propeller will be an additional 75 to 80 meters further distant from this point because of the length of the barge and tug. Therefore the noise source as detected by the fish 40 meters in front of the ship is actually about 120 meters distant. This distance is shorter for steelhead and is less than 100 meters.

2.5.1.1.7.3.1 Winter-run Exposure and Risk

Because the barge traffic occurs year round for the duration of the construction period, all migrations of juvenile and adult winter-run Chinook salmon will overlap with the projected barge traffic operations during the 5-6 years of the projected construction schedule.

The multiple barge landing locations are located in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of winter-run Chinook salmon from the Sacramento River basin. From Chipps Island to the Golden Gate, all juvenile and adult life stages of winter-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco.

Estimates for annual propeller entrainment and mortality of winter-run Chinook salmon passing through the propellers of the tugboats are based on the densities of winter-run sized Chinook salmon captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1996 through 2016. The year-round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities. Data from Jersey Point (1997-1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 3-28 below provides estimates for the annual entrainment of spring-run Chinook salmon to the three different barge landings over the course of one year for the three different propeller diameters.

Table 3-28. Estimated Annual Winter-run juvenile Propeller Entrainment for Three Barge landing Sites

Propeller Diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake 2	Annual sum Entrainment	Annual Mortality
1.3 meters	294	36	231	42	52	655	262
1.5 meters	392	48	307	56	70	873	349
1.8 meters	564	69	443	80	100	1257	503

[1]Barge traffic from either Antioch or San Francisco point of origin is "west"

[2]Barge traffic from the Port of Stockton point of origin is "east"

NMFS concludes that the proposed barge traffic will adversely affect a proportion of winter-run Chinook salmon over the course of the proposed construction of the PA.

2.5.1.1.7.3.2 Spring-run Exposure and Risk

Because the barge traffic occurs year round for the duration of the construction period, all migrations of juvenile and adult spring-run Chinook salmon will overlap with the projected barge traffic operations during the 5-6 years of the projected construction schedule.

The multiple barge landing locations are located in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of spring-run Chinook salmon from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of spring-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco.

The estimates for annual propeller entrainment and mortality of spring-run Chinook salmon passing through the propellers of the tugboats are based on the densities of spring-run-sized Chinook salmon captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1996 through 2016. The year-round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities.

Data from Jersey Point (1997-1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 3-30 and Table 3-31 below provide estimates for the annual entrainment of steelhead to the three different barge landings over the course of one year for the three different propeller diameters.

Table 3-29. Estimated Annual Spring-run juvenile Propeller Entrainment for Three Barge landing Sites

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake 2	Annual sum Entrainment	Annual Mortality
1.3 meters	2383	292	1869	339	437	5320	2128
1.5 meters	3172	389	2488	452	582	7083	2833
1.8 meters	4568	560	3583	650	838	10199	4080

[1]Barge traffic from either Antioch or San Francisco point of origin is "west"
[2]Barge traffic from the Port of Stockton point of origin is "east"

NMFS finds that the proposed barge traffic will adversely affect a proportion of spring-run Chinook salmon over the course of the proposed construction of the PA.

2.5.1.1.7.3.3 Steelhead Exposure and Risk

Because the barge traffic occurs year round for the duration of the construction period, all emigrations of juvenile CCV steelhead and upstream and downstream migrations of adult CCV will overlap with the projected barge traffic operations during the 5-6 years of the projected construction schedule.

The multiple barge landing locations are in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of CCV steelhead overlap with projected routes of the barge traffic from San Francisco.

Estimates for annual propeller entrainment and mortality of steelhead passing through the propellers of the tugboats are based on the densities of steelhead captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1998 through 2016.

The year round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities. Data from Jersey Point (1997-1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 3-30 and Table 3-31 below provide estimates for the annual entrainment of steelhead to the three different barge landings over the course of one year for the three different propeller diameters.

Table 3-30. Estimated Annual Unclipped steelhead Propeller Entrainment for Three Barge landing Sites

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake 2	Annual sum Entrainment	Annual Mortality
1.3 meters	44	5	35	6	5	96	77
1.5 meters	59	7	46	8	7	128	103
1.8 meters	85	10	67	12	10	185	148

[1]Barge traffic from either Antioch or San Francisco point of origin is “west”
[2]Barge traffic from the Port of Stockton point of origin is “east”

Table 3-31. Estimated Annual Clipped steelhead Propeller Entrainment for Three Barge landing Sites

	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake 2	Annual sum Entrainment	Annual Mortality
1.3 meters	217	27	171	31	39	484	387
1.5 meters	289	36	227	41	52	645	516
1.8 meters	417	51	327	59	74	928	743

[1]Barge traffic from either Antioch or San Francisco point of origin is “west”
[2]Barge traffic from the Port of Stockton point of origin is “east”

NMFS finds that the proposed barge traffic will adversely affect a proportion of steelhead over the course of the proposed construction of the PA.

2.5.1.1.7.3.4 Green Sturgeon Exposure and Risk

Green sturgeon can become entrained by the flow field generated by propellers on large ships, barges, tugs, or dredges. Because of their size, adult sturgeon that are unable to swim away and escape entrainment are likely to be struck by the propeller blades and either injured or killed. Juvenile sturgeon will likely have a more difficult time swimming away from the propeller’s flow field and evading entrainment, but they might be small enough to become entrained in the flow field and pass through the propeller’s wake without being struck by any of the blades. Even if a juvenile fish did become entrained and escape direct injury from being struck by a propeller blade, the fish would nevertheless be disoriented, and possibly more susceptible to predation, from having been caught in the vortex of turbulent flow trailing the propeller.

The probability of propeller entrainment will vary depending on the draft of the vessel and the size, orientation, and behavior of the fish. Because of their benthic orientation, sturgeon may be less vulnerable to propeller entrainment of shallow draft vessels and, conversely, more so to deep draft vessels.

Based on the year-round planned operation of barges throughout the action area where juvenile green sturgeon may be present during any month of the year—and through which spawning adults annually migrate between the ocean and their upstream spawning habitat—NMFS has determined that many, if not all, juvenile and spawning adult sDPS green sturgeon will be exposed to a higher risk of propeller entrainment from increased barge traffic in the channels of the Delta over a six-year period, which is likely to result in adverse effects to a medium proportion of juvenile and adult sDPS green sturgeon.

2.5.1.1.7.3.5 Fall/Late fall-run Exposure and Risk

Because barge traffic occurs year round for the duration of the construction period, all migrations of juvenile and adult fall/late fall-run Chinook salmon will overlap with the projected barge traffic operations during the five to six years of the projected construction schedule.

The multiple barge landing locations are in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of fall/late fall-run Chinook salmon from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of fall/late fall-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco.

Estimates for annual propeller entrainment and mortality of fall/late fall-run Chinook salmon passing through the propellers of the tugboats are based on the densities of fall/late fall-run-sized Chinook salmon captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1996 through 2016.

The year round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities. Data from Jersey Point (1997-1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 3-32 and Table 3-33 below provide estimates for the annual entrainment of fall/late fall-run Chinook salmon to the three different barge landings over the course of one year for the three different propeller diameters.

Table 3-32. Table F. Estimated Annual Fall run-Chinook salmon Propeller Entrainment for Three Barge landing Sites

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake 2	Annual sum Entrainment	Annual Mortality
1.3 meters	8246	1011	6466	1174	4654	21551	8621
1.5 meters	10978	1346	8609	1563	6197	28693	11477
1.8 meters	15808	1939	12397	2251	8923	41318	16527

[1]Barge traffic from either Antioch or San Francisco point of origin is "west"
[2]Barge traffic from the Port of Stockton point of origin is "east"

Table 3-33. Table LF. Estimated Annual Late Fall run-Chinook salmon Propeller Entrainment for Three Barge landing Sites

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake 2	Annual sum Entrainment	Annual Mortality
1.3 meters	77	9	60	11	12	170	68
1.5 meters	102	13	80	15	16	226	90
1.8 meters	147	18	116	21	23	325	130

[1]Barge traffic from either Antioch or San Francisco point of origin is "west"
[2]Barge traffic from the Port of Stockton point of origin is "east"

NMFS concludes that the proposed barge traffic will adversely affect a proportion of fall/late fall-run Chinook salmon over the course of the proposed construction of the PA.

2.5.1.1.7.4 Dewatering Capture/Release

Cofferdams at the NDDs, CCF, and HOR gate will be installed before construction of the PA infrastructure begins. Depending on the specific location, the in-water work window will begin as early as June and may extend through the end of November (Table 3-1).

Cofferdam installation begins with sheet pile installation. Once the cofferdam area is isolated, the action agency/applicant will implement AMM 8, Fish Rescue and Salvage Plan (Appendix 3.F of BA), which involves removing any fish remaining in the isolated cofferdam area before dewatering. Any fish present will be adversely affected, either by capture, transfer, and release, or, if capture was avoided, by becoming stranded during dewatering. Some portion of fish within the cofferdam area will be expected to die during the dewatering process.

2.5.1.1.7.4.1 North Delta Intake Locations

Construction of each intake is projected to take approximately four to five years, (Appendix 3.E of the BA) and will require approximately 42 days to construct and close the cofferdam structure at each NDD intake location.

Portions of the cofferdam will become permanent components of the intake structure when construction is completed. All in-water activities will be restricted to June 1 through October 31 to minimize exposure of listed fish species to construction-related impacts on water quality and other hazards.

Initial construction activities at each intake will involve installing a sheet pile cofferdam in the river during the first construction season, which will isolate the waterside portion of the PA infrastructure during the remaining years of construction. During this period, fish may be able to escape from the area behind the cofferdam and the adjacent bank through open gaps in the sheet pile alignment that have not undergone sheet pile installation yet. Fish that do not escape are likely to be injured or killed by the subsequent day's sheet pile installation. NMFS expects that the final days of sheet pile installation will have the highest risk of entrapping fish behind the cofferdam as the final gaps in the cofferdam alignment are closed off. Fish that are entrapped behind the cofferdam will be the subject of fish capture and relocation. The capture and relocation efforts are unlikely to be completely effective, and some fish will avoid capture and die behind the cofferdam as it is dewatered. Other fish that are captured during the dewatering process may not survive this action and die immediately or at some time afterwards due to latent injuries or stress. It is expected that the methods of capture to rescue fish can and will result in injury or death due to entanglement in seine nets or injury due to electrofishing efforts. Furthermore, water quality conditions are expected to deteriorate during the dewatering process, leading to elevated risk of stress, injury, or death of fish trapped behind the cofferdam.

2.5.1.1.7.4.1.1 Chinook Salmon Exposure and Risk

The timing of cofferdam installations at the NDD sites will greatly minimize exposure to Chinook salmon. Winter-run Chinook salmon adults are expected to be in the activity area November through June, while juveniles are expected to be outmigrating past the area October through April. Therefore, there is some likelihood that adults or juvenile winter-run Chinook salmon could be in the area during dewatering activities.

Adult spring-run Chinook salmon are not expected to be in the area during in-water work because they will move upstream between January and March. In some years, juvenile spring-run Chinook salmon migrating through the NDD locations may occur as late as June. This is likely to only occur in some years, and in small proportions (less than two percent) of the total number of outmigrating juvenile spring-run Chinook salmon.

Fall-run Chinook salmon adults are expected to be in the area December through April, and juveniles from July through December, therefore potentially exposing both to dewatering activities. Late-fall Chinook salmon adults are expected to be in the area October through April, and juveniles July through September, and again November through January. Therefore, potential exposure will occur. Adverse effects to species is expected to occur because of the overlap in dewatering activities and Chinook migration timing. Adult Chinook migrating through, however, are not expected to be adversely affected due to their ability to swim out of the open end of the cofferdam before it is closed. When activity begins, they will be expected to leave the area.

2.5.1.1.7.4.1.2 Steelhead Species Exposure and Risk

Installation of the cofferdams at the NDD intake sites has the potential to entrap both juvenile and adult CCV steelhead during construction. If cofferdam construction is initiated in June, then juvenile CCV steelhead may be entrapped behind cofferdam structures during their downstream emigration.

Similarly, if the cofferdam installation continues into the end of summer and early fall, then increasing numbers of upstream migrating adult CCV steelhead are subject to entrapment behind the cofferdam structure. Although adult steelhead have a higher likelihood and ability than juveniles to leave the cofferdam before it is closed, there may be a small proportion that remain who will be subject to fish capture or relocation. NMFS expects adverse effects to a small proportion of both juvenile and adult CCV steelhead to occur as a result of these activities.

2.5.1.1.7.4.1.3 Green Sturgeon Species Exposure and Risk

Green sturgeon that become stranded behind the sheet pile walls during cofferdam installation will likely be captured for removal and relocation before dewatering. Those individual fish that are captured by seining will be subject to handling stress during the relocation efforts. Those individual fish that are able to evade capture in a seine may instead be subject to the stress of electrofishing and then handling afterwards.

The size of adult green sturgeon makes it unlikely that they would be able to evade detection or capture in the confined area behind the cofferdam before dewatering, so NMFS does not expect any adult green sturgeon to become exposed to the adverse effects of dewatering. Some juvenile sturgeon, however, could conceivably evade capture and suffer declining water quality conditions during the dewatering process. NMFS expects that implementation of the fish rescue and salvage plan (AMM 8) will sufficiently minimize the risk of stranding so that very few sDPS green sturgeon will experience the adverse effects associated with dewatering. A small proportion of juveniles and adults will be adversely affected from capture and handling stress during relocation efforts.

2.5.1.1.7.4.2 Clifton Court Forebay

Adverse effects to salmonid species would be minimized by restricting all in-water construction to July 1 through November 30, limiting the duration of these activities to the extent practicable, and implementing AMM8.

The installation of cofferdams in the CCF work area will include installing the siphon infrastructure in the future NCCF (two work seasons), the partition dike cofferdam across the width of the existing CCF (two work seasons), and the east and west dikes adjacent to the existing levee embankments to facilitate construction of the new SCCF embankments (one season).

The siphon structure will require installing a cofferdam enclosure to isolate half of the inlet channel to the Skinner Fish Protection Facility in each of two consecutive work seasons. The east and west embankment dikes will require that the space between the cofferdam and existing levee embankments be dewatered and fish capture or relocation operations carried out per AMM 8 when the cofferdams are fully installed.

The partition dike across the width of the existing CCF will be constructed in one season, except for two, 100-foot-wide gaps in the eastern and western ends of the cofferdam wall. These gaps will be closed the following work season when the new expansion area to the south of the existing CCF is flooded and the existing earthen embankment removed to design elevation. Once the gaps are closed off with sheet piles, the entire NCCF area will be dewatered and a fish capture or relocation operation conducted per AMM 8.

2.5.1.1.7.4.2.1 Salmonid Species Exposure and Risk

The timing of the in-water work window is expected to minimize the exposure of salmonids to entrapment behind the cofferdams during construction. Typically, salvage of listed salmonids at the CVP and SWP fish collection facilities ends in June, and by July water temperatures in the CCF are consistently in excess of thermal preferences for Chinook salmon or steelhead (greater than 22°C). This typically indicates environmental conditions that are inhospitable to salmonids and minimizes the potential for salmonids to be present in the forebay during the start of in-water construction in July.

The projected duration of cofferdam installation is 85 days for the eastern and western embankment cofferdams, 72 days each work season for the NCCF siphon, 86 days to install the partition cofferdam across the CCF, and 30 days to close the partition dike in the second construction season.

If in-water work starts for the cofferdams on July 1, then completion of the work should be no later than the end of September if work is continuous and approximately the end of October if limited to a 5-day work week. The risk of salmonids entering the cofferdam structures at the end of the work window increases by the end of October, but is still considered low based on historical salvage records at the CVP and SWP projects. Therefore, it is still unlikely that more than a few individual salmonids would be present in the areas behind the cofferdams during the dewatering process and be the subject of a fish rescue and salvage. NMFS expects, however, that there may be adverse effects to a small proportion of salmonids.

2.5.1.1.7.4.2.2 Green Sturgeon Species Exposure and Risk

As described for the NDD intake locations in section *2.5.1.1.7.4.1 North Delta Intake Locations*, very few individual green sturgeon, if any, will be exposed to the adverse effects associated with dewatering at the CCF, and only a small proportion of juveniles, sub-adults, and adults will experience the stress of capture and handling during relocation efforts. This potential for exposure to dewatering in relation to the CCF location is likely even further reduced because of how far removed in the south Delta the site is from the main migratory path of green sturgeon between the ocean and the Sacramento River and the relatively low numbers and density of sturgeon expected to occur in this area.

2.5.1.1.7.4.3 HOR Gate

Construction of the HOR gate is expected to take two years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel of Old River during the first phase and the other half during the second phase. All in-water construction work, including cofferdam installation, will be restricted to August 1 through October 31 to minimize or avoid potential effects on listed fish species. AMM 8 will be implemented to minimize impacts to fish during implementation of the fish capture or relocation plan.

2.5.1.1.7.4.3.1 Chinook Salmon Species Exposure and Risk

Limiting in-water work at the HOR Gate to the August 1 through October 31 work window is expected to minimize exposure to Chinook salmonid species because:

- Winter-run Chinook salmon are not expected to be present near the HOR Gate because it is far from their migration routes. Furthermore, the winter-run Chinook salmon-sized juveniles that have been found in the area of the HOR Gate have only been found there in March and April.
- Juvenile spring-run Chinook salmon originating from the Sacramento River basin are not expected to be present near the HOR Gate because it is far from their migration routes. San Joaquin River basin spring-running fish and those from the reintroduced experimental population have been found in the area of the HOR Gate in April and May.

- Late fall-run Chinook salmon are not expected to be present in the vicinity of the HOR Gate because this area is far from any migration routes used by this run.
- Juvenile fall-run Chinook salmon are expected to be present in the vicinity of the HOR Gate from April through June. And while adult fall-run will be migrating through the action area July through December, only a small proportion of the Central Valley population is expected to pass near the HOR Gate.

A small proportion of Chinook salmon are expected to be adversely effected as a result.

2.5.1.1.7.4.3.2 Steelhead Species Exposure and Risk

Juvenile CCV steelhead are unlikely to be present in the HOR Gate construction area during cofferdam installation based on their emigration timing. The construction of the cofferdam structures in Old River will occur from August through October, when few juvenile steelhead have been observed in either regional monitoring or in fish salvage at the CVP and SWP facilities. Only a minimal amount of temporal overlap with the presence of juvenile CCV steelhead is expected.

Based on regional monitoring data and salvage data from the SWP and CVP fish collection facilities, less than one to two percent of the annual juvenile emigration from either basin is expected to occur during the proposed work windows in 2020 and 2021. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location.

Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. Because the cofferdam installation at the HOR gate occurs August through October in 2020 and 2021, coupled with the location of the HOR Gate, only those adult steelhead migrating into the San Joaquin River basin during these months will be affected. No steelhead from the Sacramento River basin are anticipated to be present at this location at any time.

It is anticipated that only a small proportion of the annual adult upriver migration will overlap with pile driving associated with the cofferdam installation. It is expected that only fish migrating past the cofferdam during the final installation of the sheet piles will be at risk for entrapment within the cofferdam before dewatering. Earlier arriving fish will have either had time to escape the cofferdam enclosure through openings in the wall or will have died or been injured during the pile-driving actions while trapped in the enclosure.

Fish that are entrapped behind the cofferdam will be the subject of fish capture and relocation per AMM 8. The capture or relocation effort is unlikely to be completely effective. Some fish will avoid rescue and die behind the cofferdam as it is dewatered. Other fish that are rescued during the dewatering process may not survive this action and die immediately or at some time afterwards due to latent injuries or stress.

It is expected that the methods of capture to rescue fish can and will result in injury or death due to entanglement in seine nets or injury due to electrofishing efforts for a proportion of the affected fish. Furthermore, water quality conditions are expected to deteriorate during the dewatering process, leading to elevated risk of stress, injury, or death of fish trapped behind the cofferdam. Although unlikely, there is some possibility a few individual juvenile steelhead will be exposed and adversely effected. Adult steelhead would more likely be exposed, but more likely to leave the area of activity. However, a small proportion of adult steelhead may nonetheless be subject to adverse effects.

2.5.1.1.7.4.3.3 Green Sturgeon Species Exposure and Risk

Very few green sturgeon, if any, will be exposed to dewatering activities at the HOR gate. The risk of exposure is low because of the distance from the main migratory path of green sturgeon (between the ocean and the Sacramento River), which results in relatively low numbers and density of green sturgeon expected to occur in this area. Therefore, a very small proportion of juvenile green sturgeon will experience the stress of capture and handling during relocation efforts.

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